Optimization of textural properties of predried and deep-fat-fried carrot slices as a function of process conditions

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Outline

- **Introduction to Deep-Fat-Frying**
- Aim
- What we did
- What we obtained
- Let’s Discuss it
- Conclusion

Deep-Fat-Frying

- Popular cooking method
  - Especially for vegetables
    - Carrot
- Frying
  - Using vegetable oil
  - At high temperature levels
  - For certain time

Deep-Fat-Frying

- What is going on during deep-fat-frying?
  - Type of dehydration process including simultaneous heat and mass transfer
    - Rapid temperature raise
    - Water molecules evaporate
    - Increasing internal pressure of frying material
    - Decreasing moisture content
    - Case hardening
    - Crust formation depending on frying material

Deep-Fat-Frying

- Important points for evaluation of deep-fat-fried products
  - Oil uptake
  - Moisture content
  - **Textural properties**
  - Taste, flavor, aroma
  - Surface color
  - Shape, size etc.

Deep-Fat-Frying

- Textural properties should meet the consumer expectations
  - Texture is significant and determinative characteristic for fried products for consumer's perception
  - Vary depending on type of product

Deep-Fat-Frying

- Factors affecting textural properties of final fried product
  - Raw material
    - Type
    - Composition
  - Preprocess
    - Boiling
    - **Drying**
    - Other possible applications

Deep-Fat-Frying

- Main project was about the control of oil absorption of fried carrot slices.
- As a pretreatment, drying was performed to decrease the moisture content of carrot slices
- There is a relation between initial moisture content of frying material and its final oil content.
- Less moisture content resulted in limited oil absorption.

Deep-Fat-Frying

- As a pretreatment,
  - Conventional oven drying
  - Microwave oven drying

  To decrease the moisture content of carrot slices

Deep-Fat-Frying

- Factors affecting textural properties of final fried product
  - Frying process
    - Oil temperature
    - Process time
    - Frying material/Oil volume (w/v)

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Aim of the study

- Main purpose of the current study as a part of main project was
  - To evaluate the change of textural properties of deep-fat-fried product , initial moisture content was lowered by two different drying methods (conventional oven and microwave oven).
  - To optimize the predrying and deep-fat-frying process conditions in terms of textural properties

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Material & Methods

- Carrots were purchased from local producer's orchard to avoid changes due to carrot type and environmental-climatic variations.
- Stored @ +4^{o}C
- Before process
  - washed
  - peeled
  - sliced (slice thickness selected according to preliminary studies to determine consumer demands towards conventionally fried carrot slices)
  - boiled for 90 sec in boiling water (~ 100^{o}C) (enough for enzyme inactivation)

How was carrot slice predried and fried?

- Predrying
  - Conventional oven
    - Constant air flow (around 0.8 m/sec)
    - temperature is adjustable (from 50^{o}C to 300^{o}C)
  - Microwave oven
    - Temperature is adjustable (from 30^{o}C to 100^{o}C)
- Deep-fat-frying
  - Industrial fryer
    - Temperature is adjustable (from 50^{o}C to 200^{o}C)

Experimental Design

- For optimization experimental design should be created using different tools including statistical based ones
- For conventional predrying & frying
  - Central Composite Design
    - 4 independent variables at 5 levels with 4 central points
- For microwave predrying & frying
  - Full Factorial Design
    - 3 independent variables at 3 levels

Coded & Real Values of Independent Variables of Conventionally Predrying & Deep-Fat-Frying

Independent Variable	Real/Coded Values of Variables				
Drying Temperature (°C)	41 / -2	48 / -1	55 / 0	62 / 1	69 / 2
Weight Loss (%)	10 / -2	12.5 / -1	15 / 0	17.5 / 1	20 / 2
Frying Temperature (°C)	120 / -2	135 / -1	160 / 0	165 / 1	180 / 2
Frying Time (sec)	120 / -2	240 / -1	360 / 0	480 / 1	600 / 2

Experimental Design of Conventional Predrying & Deep-Fat-Frying

Run Order	Drying Temperature	Weight Loss	Frying Temperature	Frying Time
1	-1	-1	1	1
2	1	-1	-1	1
3	1	-1	1	1
4	0	0	2	0
5	0	0	0	-2
6	0	0	0	0
7	1	1	-1	1
8	-1	1	1	-1
9	0	0	0	0
10	-1	1	-1	-1
11	-2	0	0	0
12	2	0	0	0
13	-1	-1	1	-1
14	-1	1	-1	1
15	0	0	-2	0
16	0	-2	0	0
17	-1	1	1	1
18	0	2	0	0
19	1	-1	-1	-1
20	1	1	1	1
21	-1	-1	-1	1
22	-1	-1	-1	-1
23	1	1	1	-1
24	0	0	0	2
25	1	1	-1	-1
26	0	0	0	0
27	1	-1	1	-1
28	0	0	0	0

Coded & Real Values of Independent Variables of Predrying Using Microwave oven & Deep-Fat-Frying

Independent Variable	Real/Coded Values of Variables		
Weight Loss (%) in Microwave Oven	10/ -1	15/ 0	20/ 1
Frying Temperature (°C)	140 / -1	160 / 0	180 / 1
Frying Time (sec)	200 / -1	350 / 0	500 / 1

Experimental Design of Microwave Predrying & Deep-Fat-Frying

Run Order	Weight Loss	Frying Temperature	Frying Time
1	0	0	0
2	1	1	1
3	1	0	0
4	1	0	1
5	0	-1	1
6	-1	1	0
7	-1	1	1
8	0	-1	-1
9	0	1	0
10	1	1	0
11	0	0	1
12	1	-1	1
13	1	0	-1
14	-1	0	0
15	1	-1	-1
16	-1	0	1
17	1	-1	0
18	0	1	-1
19	0	1	1
20	-1	-1	1
21	-1	1	-1
22	1	1	-1
23	0	0	-1
24	-1	-1	0
25	0	-1	0
26	-1	0	-1
27	-1	-1	-1

Textural Properties

- Predried and Fried Carrot Slices were subjected to texture analysis.
  - TPA Analysis (cylindirical prob-30 mm diameter)
    - hardness
    - elasticity
    - cohesiveness
    - chewiness
  - Cutting Hardness (LKB prob)
    - cutting hardness

Optimization

- Statistical method
  - Response Surface Methodology
    - Minitab Statistical Package Program
  - Full Quadratic Model

    - For conventional drying and frying

$$Z = \beta_0 + \sum_{i=1}^{4} \beta_i X_i + \sum_{i=1}^{4} \beta_{ii} X_i^2 + \sum_{i=1}^{1} \sum_{j=i+1}^{2} \beta_{ij} X_i X_j + \sum_{i=3}^{3} \sum_{j=i+1}^{4} \beta_{ij} X_i X_j$$

    - For microwave drying and frying

$$Z = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=2}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j$$

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Textural properties measured for conventionally predried and fried carrot slices

Run Order	Hardness, g force	Elasticity	Cohesiveness	Chewiness	Cutting force, g force
1	494.10	7.25	0.77	2746.34	418.42
2	491.29	8.98	0.35	5223.12	762.95
3	747.02	7.35	0.35	7401.48	871.39
4	420.07	3.72	0.16	2519.88	401.29
5	2055.64	16.47	0.85	29136.72	1137.52
6	492.18	4.49	0.33	2001.03	662.77
7	836.92	6.53	0.69	11768.32	638.08
8	637.78	8.46	0.50	4370.96	785.44
9	374.93	4.13	0.17	3159.75	1065.72
10	1254.31	10.80	0.53	16388.11	925.73
11	1029.35	3.60	0.17	4554.69	1041.91
12	697.35	9.11	0.34	6673.15	941.92
13	1003.17	10.94	0.70	9427.18	736.27
14	1142.03	8.58	0.50	3288.18	667.85
15	2605.95	4.34	0.85	15615.83	855.06
16	699.12	7.43	0.51	4980.77	1236.99
17	605.08	2.98	0.13	3662.58	907.23
18	301.12	3.00	0.10	2300.00	888.83
19	2105.69	18.18	0.87	33048.78	1513.50
20	648.90	5.00	0.16	2950.00	413.10
21	1883.51	4.20	0.84	3196.26	950.37
22	2871.82	12.67	0.85	30828.77	1056.23
23	1204.07	8.37	0.51	9090.02	1017.36
24	597.44	6.68	0.61	5957.69	585.70
25	1248.08	16.20	0.70	21379.64	1228.83
26	132.02	0.00	0.30	1990.00	689.77
27	770.65	14.45	0.85	8535.15	992.32
28	1050.38	4.18	0.39	2376.30	846.08

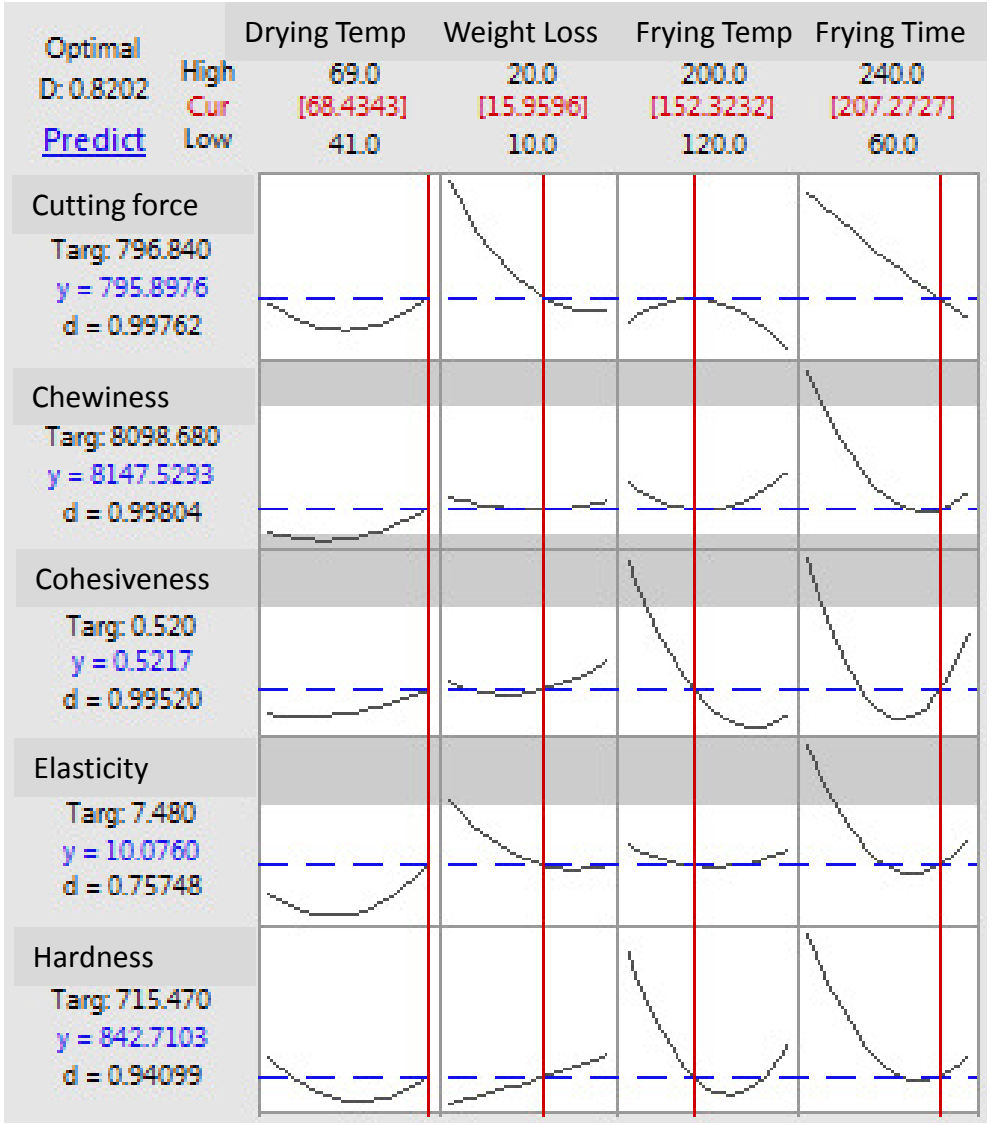
Developed models and corresponding performance parameters of conventionally predried and fried carrot slice's textural properties

Model coefficients	Hardness, g force		Elasticity		Cohesiveness		Chewiness		Cutting force, g force	
Model Sabiti Etiketi	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value
intercept	512.38	*	3.20	*	0.30	**	2381.77	ns	816.09	***
DTemp	-208.60	ns	2.52	*	0.00	ns	2477.09	ns	65.83	ns
WL	-298.84	ns	-2.17	*	-0.22	**	-2739.23	ns	-117.84	ns
FTemp	-841.22	***	-1.88	ns	-0.23	**	-8594.12	***	-209.13	*
FTim	-596.93	**	-5.73	***	-0.18	*	-11599.20	***	-310.83	***
DTemp*Dtemp	398.15	ns	4.91	*	0.05	ns	4474.96	ns	163.60	ns
WL*WL	34.92	ns	3.78	ns	0.10	ns	2501.42	ns	234.60	ns
FTemp*Ftemp	1047.81	**	2.59	ns	0.30	*	7928.90	*	-200.13	ns
FTim*Ftim	861.34	*	10.14	***	0.52	***	16408.25	***	33.30	ns
Dtemp*WL	609.18	ns	-2.15	ns	0.29	ns	2367.04	ns	-241.94	ns
FTemp*FTim	501.39	ns	2.48	ns	-0.15	ns	15876.63	***	195.95	ns
Regression	***		***		***		***		**	
R^2	78.6		82.1		75.5		90.4		70.1	
R^2_{adj}	66.0		71.6		61.1		84.7		52.5	
Lack-of-fit	ns		ns		ns		**		ns	

*, p≤0.05; **, p≤0.01; ***,p≤0.001, ns: statistically non-significant

DTemp: Drying temperature (°C), WL: Weight loss (%), FTemp: Frying temperature (°C), FTim: Frying time (sec)

Optimal process conditions for desired values of corresponding responses of conventionally dried and fried carrot slices



Textural properties measured for predried in microwave oven and fried carrot slices

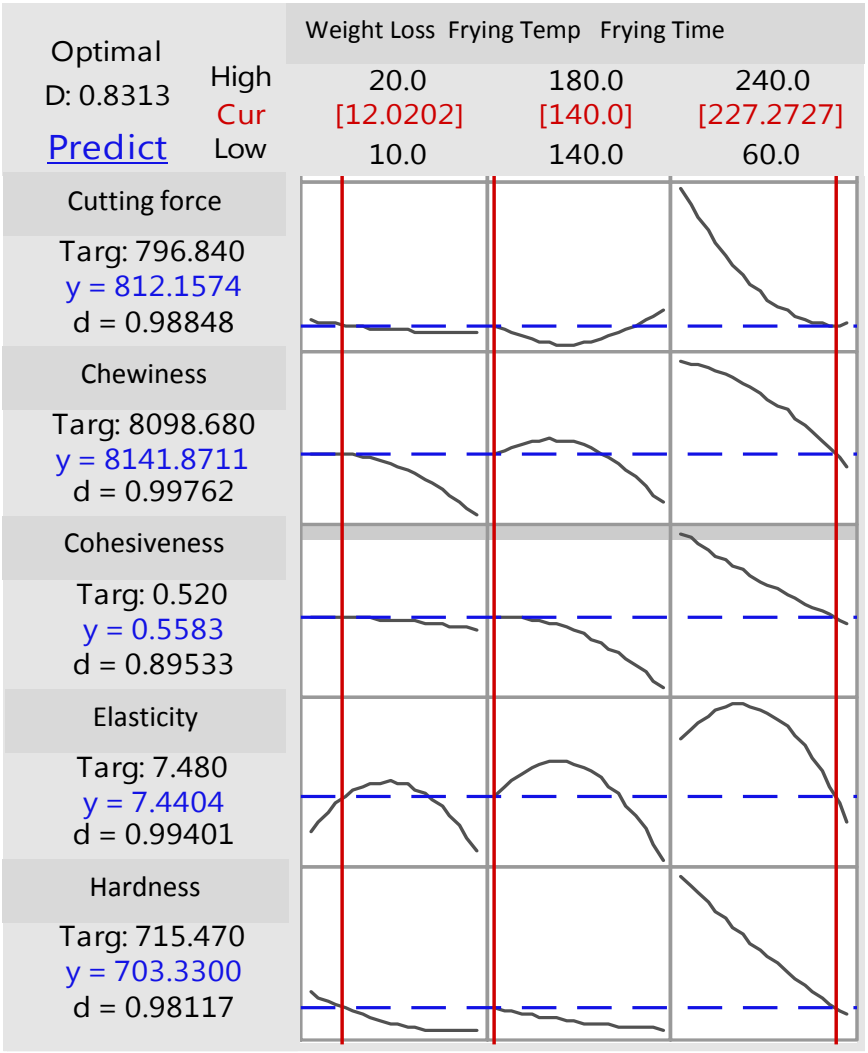
Run Order	Hardness, g force	Elasticity	Cohesiveness	Chewiness	Cutting force, g force
1	1101.22	18.63	0.67	17980.71	896.39
2	169.63	0.86	0.28	57.62	1035.09
3	461.42	12.87	0.54	7185.23	776.04
4	138.97	1.79	0.43	37.61	466.35
5	559.64	3.29	0.38	2125.79	783.24
6	444.34	5.01	0.28	6841.00	713.91
7	163.89	2.07	0.17	134.72	928.47
8	2294.74	8.45	0.83	17203.22	1566.36
9	611.27	8.12	0.26	5055.00	723.34
10	771.65	4.30	0.26	2229.00	1123.72
11	176.15	6.96	0.39	4106.00	369.84
12	70.92	3.12	0.47	100.09	819.33
13	1382.92	9.01	0.83	7893.84	1571.29
14	1314.98	16.32	0.65	16307.72	935.99
15	2322.30	12.34	0.88	12394.11	1949.03
16	548.87	6.12	0.44	5892.00	493.61
17	1074.70	11.87	0.68	11387.37	1058.99
18	1088.61	16.10	0.66	12929.68	2050.40
19	171.18	2.98	0.37	225.24	1365.27
20	748.40	5.57	0.65	9155.67	958.91
21	1414.92	9.75	0.53	17158.30	1716.83
22	1040.12	4.12	0.34	5559.23	1182.99
23	1637.41	18.55	0.86	26248.23	1411.81
24	2257.98	10.10	0.86	17042.78	1118.68
25	896.79	16.07	0.67	13331.84	1073.59
26	2558.09	10.61	0.69	23273.52	2126.19
27	3537.92	5.60	0.89	13044.46	1926.10

Developed models and corresponding performance parameters of predried in microwave oven and fried carrot slice's textural properties

Model coefficients	Hardness, g force		Elasticity		Cohesiveness		Chewiness		Cutting force, g force	
Model Sabiti Etiketi	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value
intercept	831.71	*	16.6182	***	0.611766	***	15062.0	***	771.916	***
WL	-308.71	***	-0.6032	ns	-0.024588	ns	-3444.8	***	-51.993	ns
FTemp	-438.211	***	-1.2822	ns	-0.176086	***	-2533.1	**	-23.013	ns
FTim	-807.187	***	-3.4305	***	-0.161492	***	-6326.1	***	-460.049	***
WL*WL	186.000	ns	-3.7132	**	-0.018118	ns	-2373.2	ns	23.389	ns
FTemp*Ftemp	55.496	ns	-3.9997	**	-0.087511	*	-3993.0	*	222.179	*
FTim*Ftim	119.777	ns	-4.4039	**	0.020801	ns	-2065.7	ns	326.656	**
FTemp*FTim	311.419	**	-0.8048	ns	0.031397	ns	-330.8	ns	104.885	ns
Regression	***		***		***		***		***	
R^2	90.96		74.5		85.4		82.9		78.7	
R^2_{adj}	87.55		65.2		80.1		76.6		70.8	
Lack-of-fit	ns		ns		ns		ns		ns	

*, p≤0.05; **, p≤0.01; ***,p≤0.001, ns: statistically non-significant
WL: Weight loss (%), FTemp: Frying temperature (°C), FTim: Frying time (sec)

Optimal process conditions for desired values of corresponding responses of dried in microwave oven and fried carrot slices



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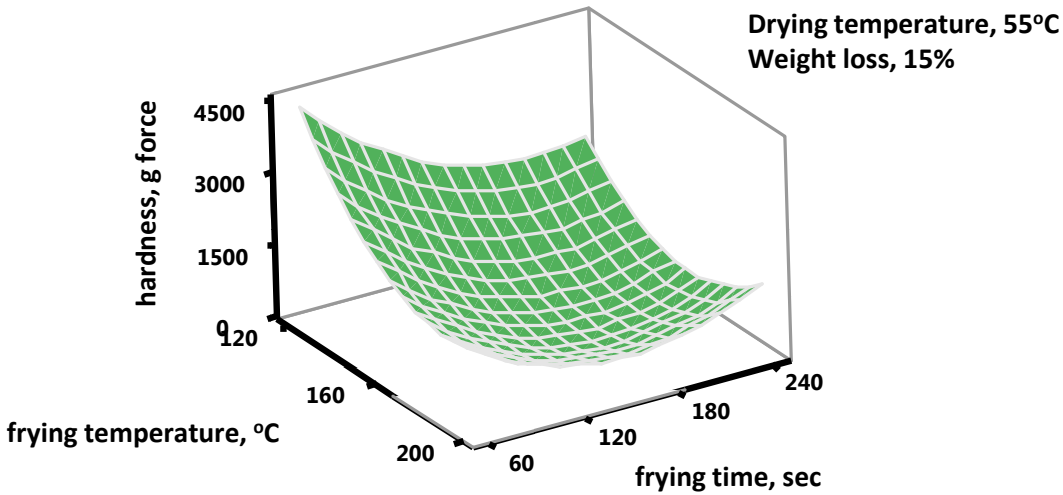

Figure 1. Change of hardness of carrot slices conventionally predried and fried under effects of frying temperature and time

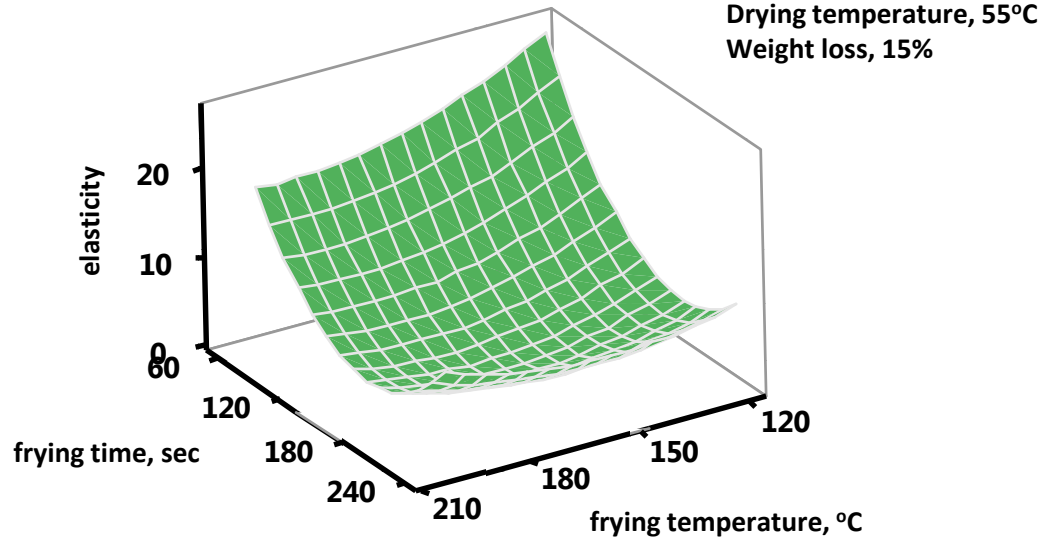

Figure 2. Change of elasticity of carrot slices conventionally predried and fried under effects of frying temperature and time

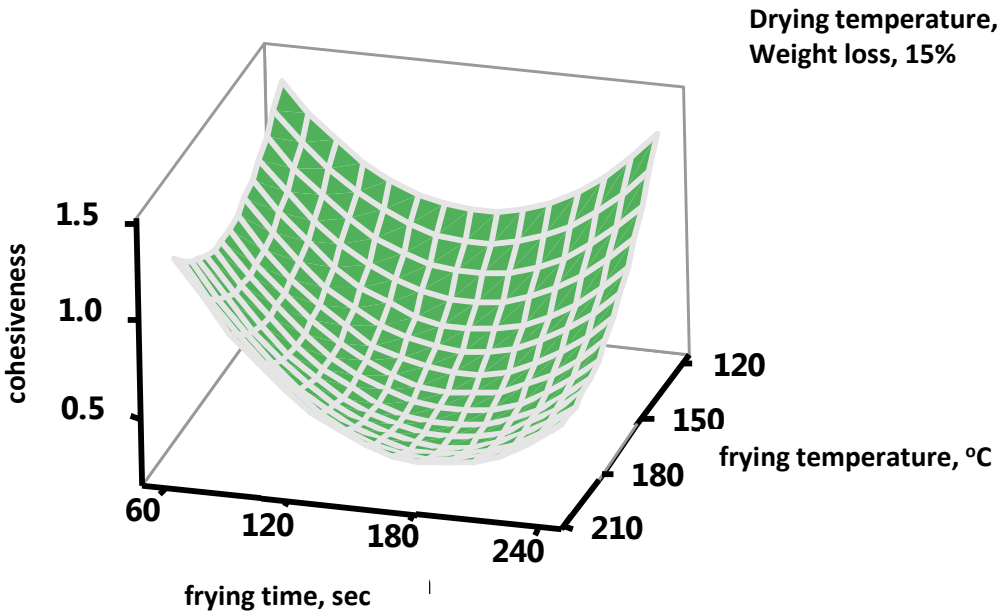

Figure 3. Change of cohesiveness of carrot slices conventionally predried and fried under effects of frying temperature and time

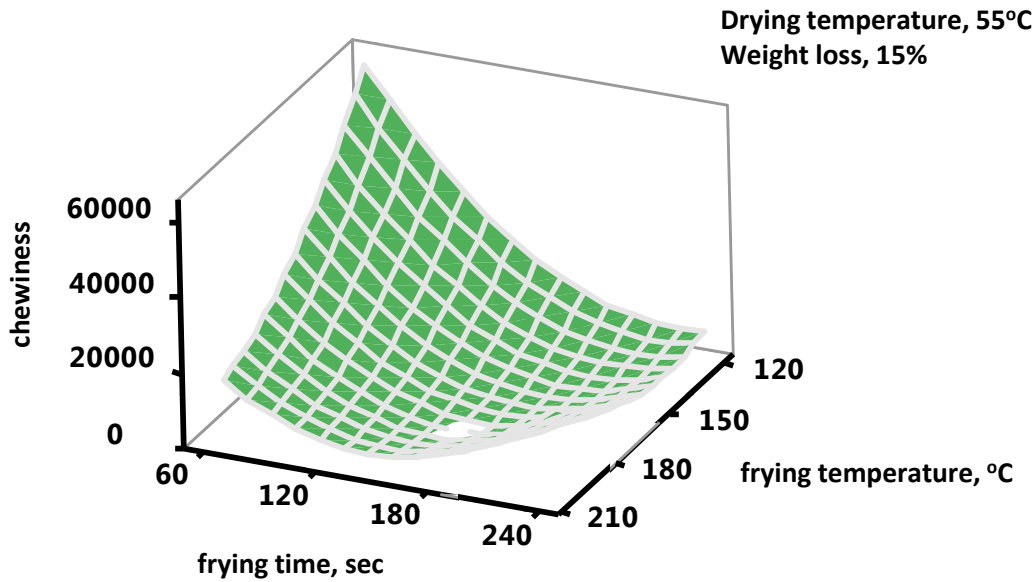

Figure 4. Change of chewiness of carrot slices conventionally predried and fried under effects of frying temperature and time

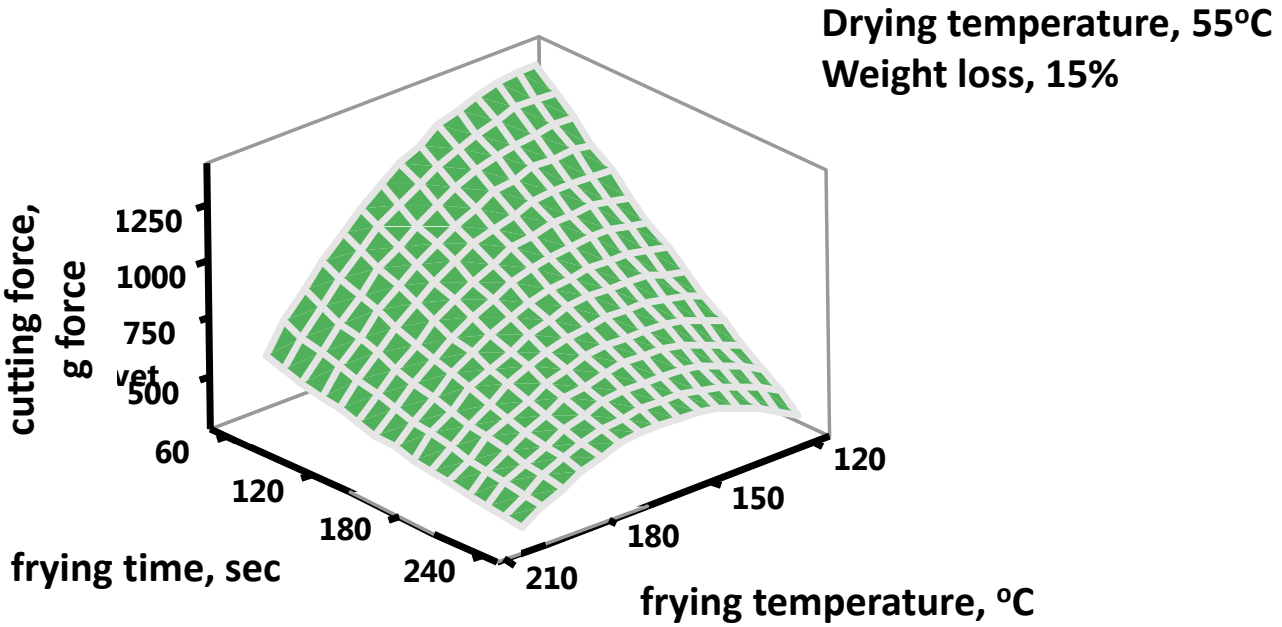

Figure 5. Change of cutting force of carrot slices conventionally predried and fried under effects of frying temperature and time

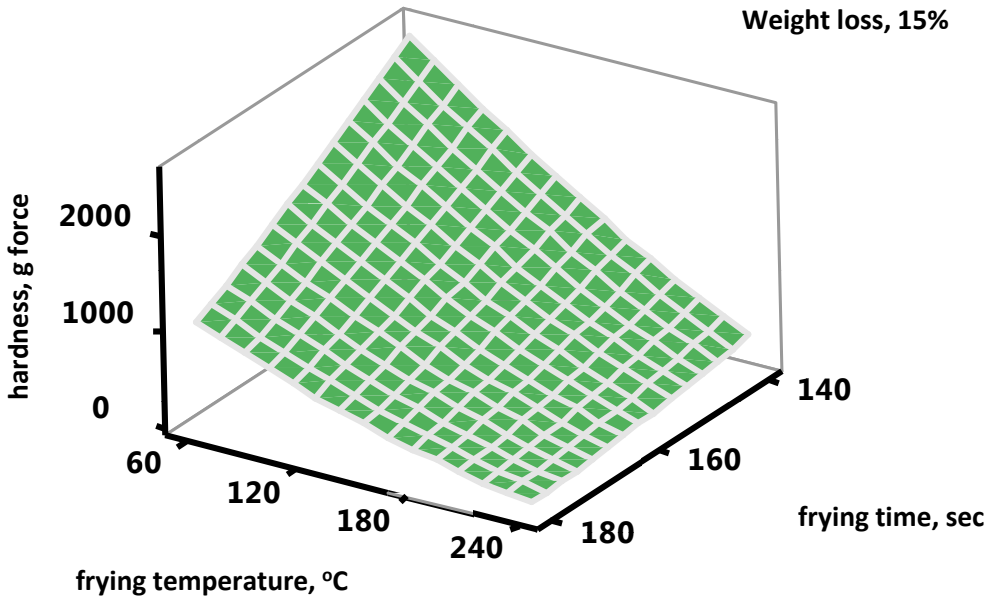

Figure 6. Change of hardness of carrot slices predried in a microwave and fried under effects of frying temperature and time

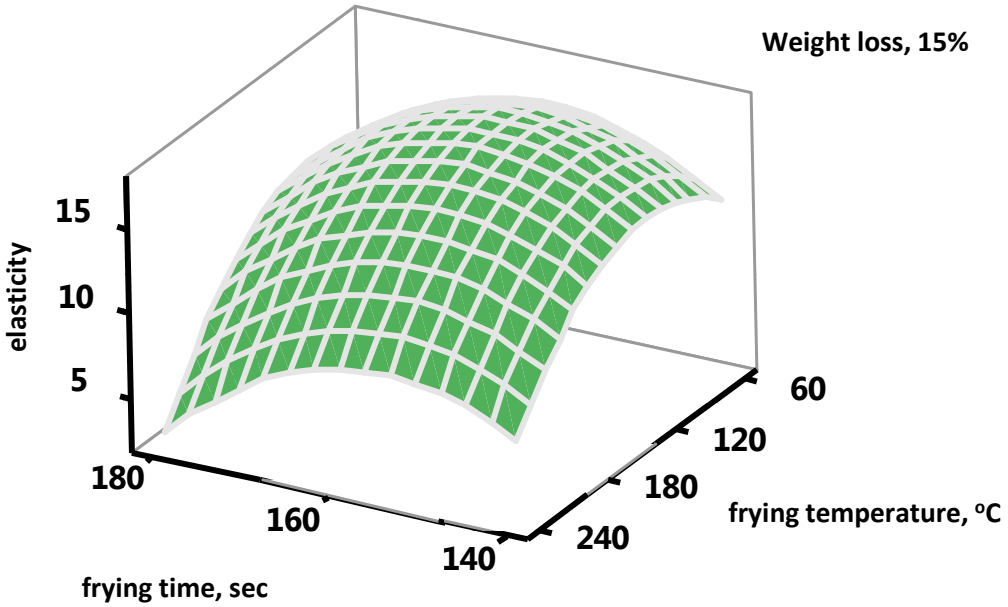

Figure 7. Change of elasticity of carrot slices predried in a microwave and fried under effects of frying temperature and time

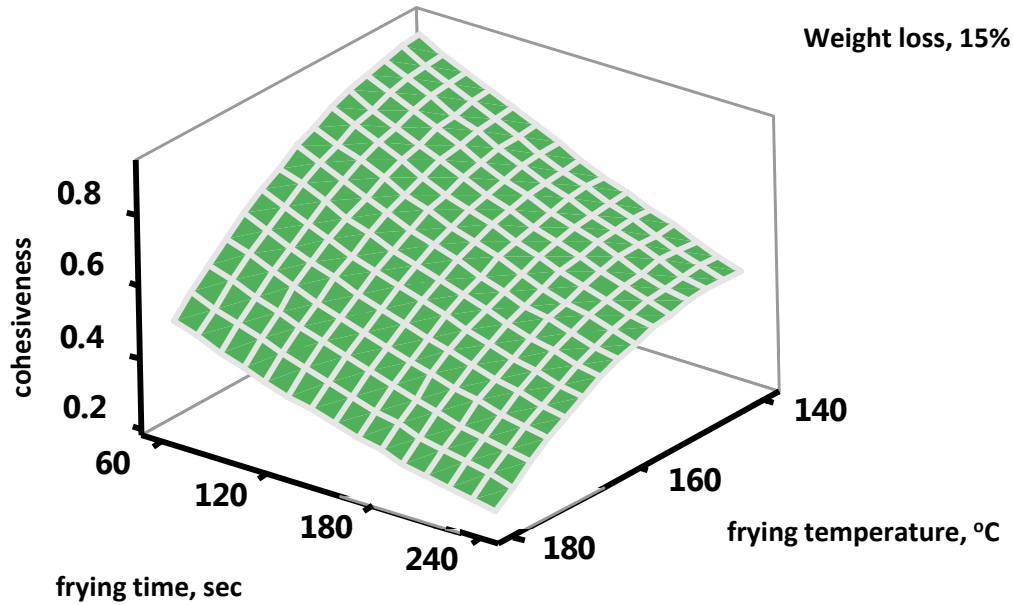

Figure 8. Change of cohesiveness of carrot slices predried in a microwave and fried under effects of frying temperature and time

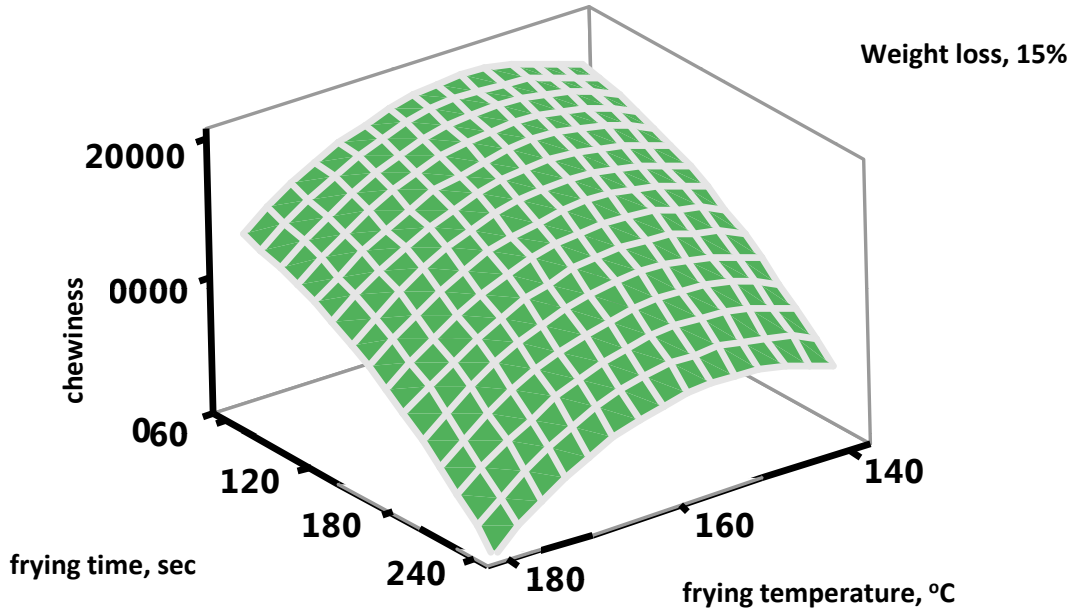

Figure 9. Change of chewiness of carrot slices predried in a microwave and fried under effects of frying temperature and time

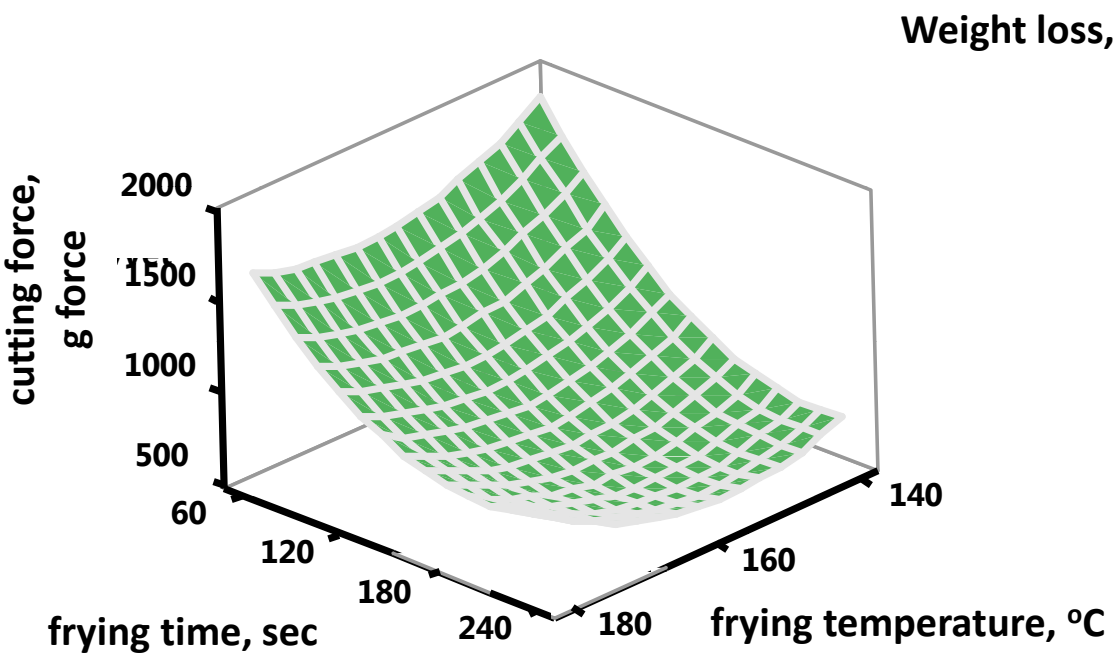

Figure 10. Change of cutting force of carrot slices predried in a microwave and fried under effects of frying temperature and time

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It could be suggested that

- Partial drying before frying is important pretreatment in terms of food characteristics.
- Texture is one of them and mainly affected by frying conditions and partially predrying ones.
- Weight loss is the main factor affecting textural properties of carrot slices during predrying carried according to both drying method in case of the range of parameters studied.
- Studied parameters ranges were not severe to modify textural properties of carrot slices, but its partial effects on moisture content directly affects further frying process, so indirectly textural properties.

Acknowledgements

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Thank you for your attentions…