Optimization of oil uptake 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
    - Transition of water vapor throughout solid matrix
    - Simultaneously partial oil absorption by solid matrix
    - Changes in textural properties of 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

- Oil uptake is the main concern of deep-fat-fried foods
  - High oil content means high calorie
    - Possible obesity reason
    - Rising related health problems
      - Cardiovascular disorders
      - Heart diseases
      - High tension

Deep-Fat-Frying

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

Deep-Fat-Frying

- Main objective was 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 results in limited oil absorption.

Deep-Fat-Frying

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

To decrease the moisture content of carrot slices before frying process

Deep-Fat-Frying

- Factors affecting oil content of final fried product
  - Frying process
    - Oil temperature
    - Process time
    - Pretreatment

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Aim of the study

- Main purpose of the current study was
  - To evaluate the change of oil uptake 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 oil uptake of final fried carrot slices

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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

Oil Uptake

- Predried and Fried Carrot Slices were subjected to Soxhlet extraction to determine their oil content.
  - Fried carrot slices were dried in a conventional oven at 60^{o}C under vacuum before oil extraction.
  - Soxhlet extraction using hexane for 5 hours
  - Oil content was calculated as dry bases.

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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Oil uptake measured for conventionally predried and fried carrot slices

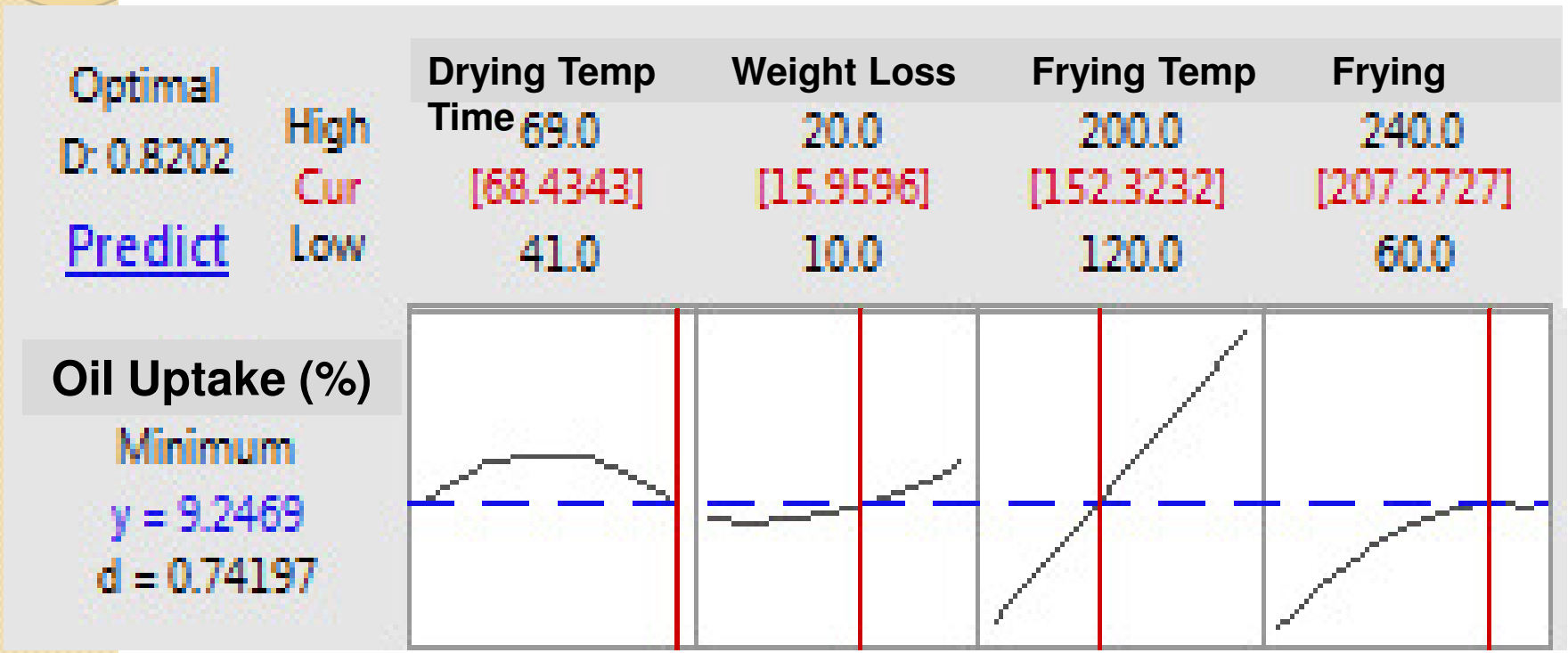
Run Order	Oil Up take (%)
1	13.25
2	7.48
3	14.37
4	18.71
5	5.66
6	10.95
7	8.48
8	8.86
9	12.78
10	5.84
11	9.07
12	9.68
13	11.01
14	9.36
15	5.88
16	9.82
17	21.76
18	17.02
19	5.65
20	15.34
21	8.33
22	4.90
23	11.49
24	14.00
25	7.85
26	11.02
27	10.16
28	11.67

Model	Oil Up take (%)	
Model coefficients	coefficient	p-value
intercept	11.60	*
DTemp	-0.10	ns
WL	2.35	ns
FTemp	6.17	***
FTim	4.11	**
DTemp*DTemp	-2.88	ns
WL*WL	1.17	ns
FTemp*FTemp	0.05	**
FTim*FTim	-2.43	*
Dtemp*WL	-0.71	ns
FTemp*FTim	3.45	ns
Regression	***	
R^2	88.2	
R^2_{adj}	81.2	
Lack-of-fit	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)

Developed models and corresponding performance parameters of conventionally predried and fried carrot slice's oil uptake

Optimal process conditions for desired value of corresponding response of conventionally dried and fried carrot slices



Oil uptake measured for predried in microwave oven and fried carrot slices

Run Order	Oil Up take (%)
1	13.17
2	43.59
3	15.85
4	30.45
5	13.91
6	21.62
7	34.92
8	9.20
9	28.02
10	17.08
11	35.28
12	21.41
13	8.53
14	10.44
15	5.56
16	34.22
17	8.55
18	8.39
19	42.96
20	11.18
21	7.27
22	12.94
23	7.02
24	6.87
25	10.78
26	7.53
27	6.10

Model	Oil Up take (%)	
Model coefficients	coefficient	p-value
intercept	16.49	***
WL	1.32	ns
FTemp	6.85	***
FTim	10.85	***
WL*WL	-1.85	ns
FTemp*Ftemp	-0.81	ns
FTim*Ftim	4.21	**
FTemp*FTim	5.60	***
Regression	***	
R^2	93.7	
R^2_{adj}	91.3	
Lack-of-fit	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)

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

Optimal process conditions for desired value of corresponding response of dried in microwave oven and fried carrot slices

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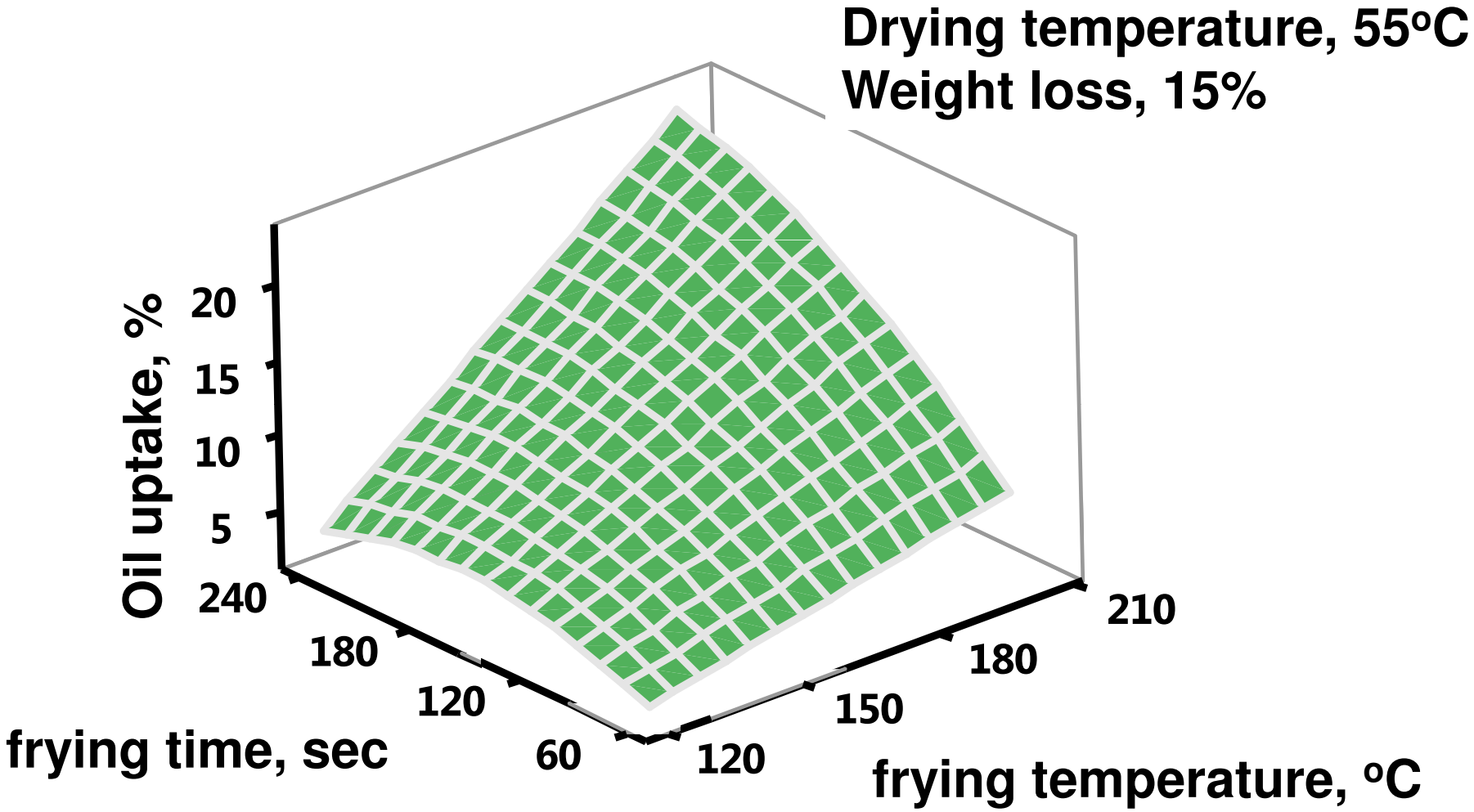

Figure 1. Change of oil uptake of carrot slices conventionally predried and fried under effects of frying temperature and time

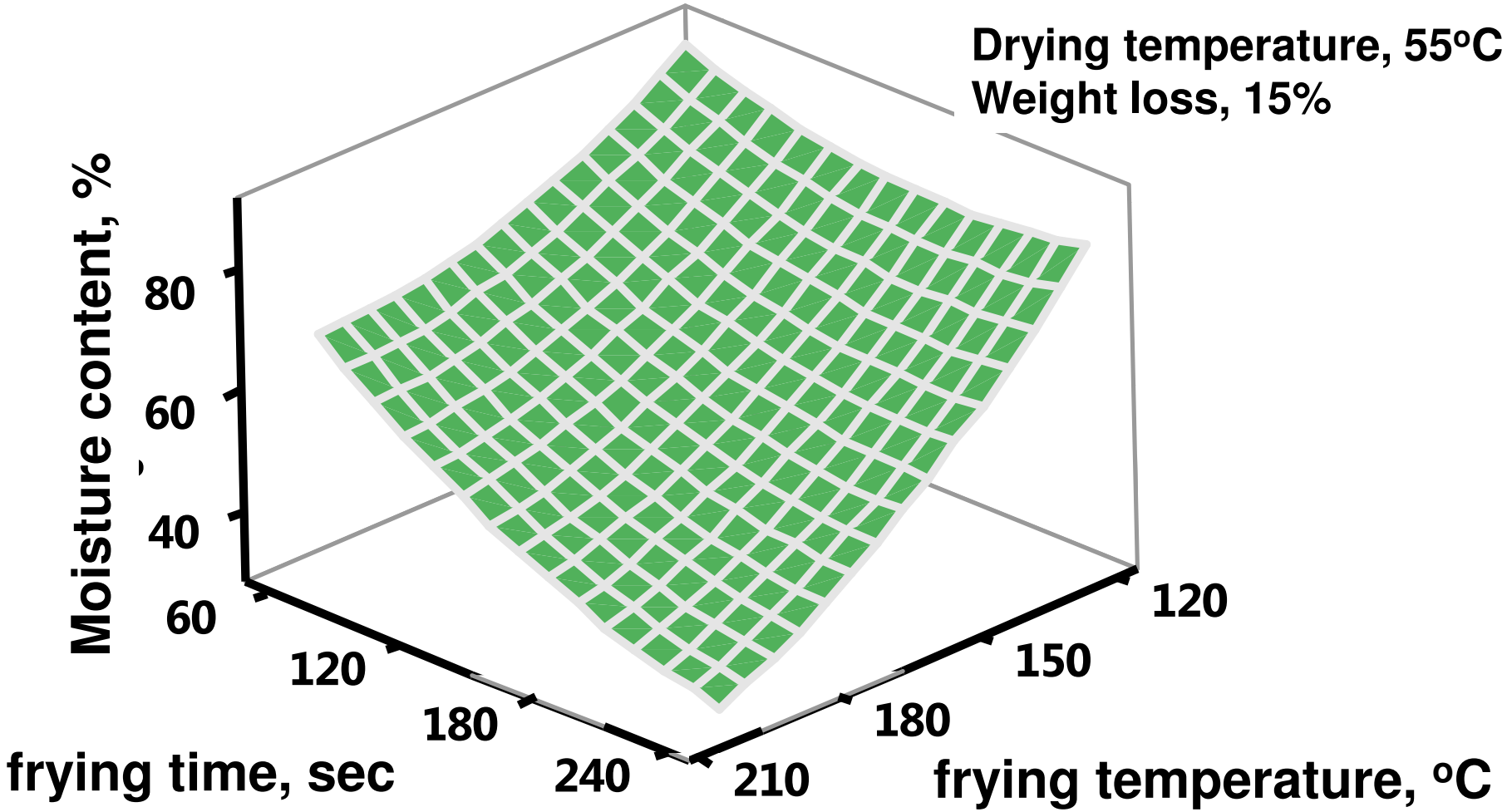

Figure 2. Change of moisture content of carrot slices conventionally predried and fried under effects of frying temperature and time

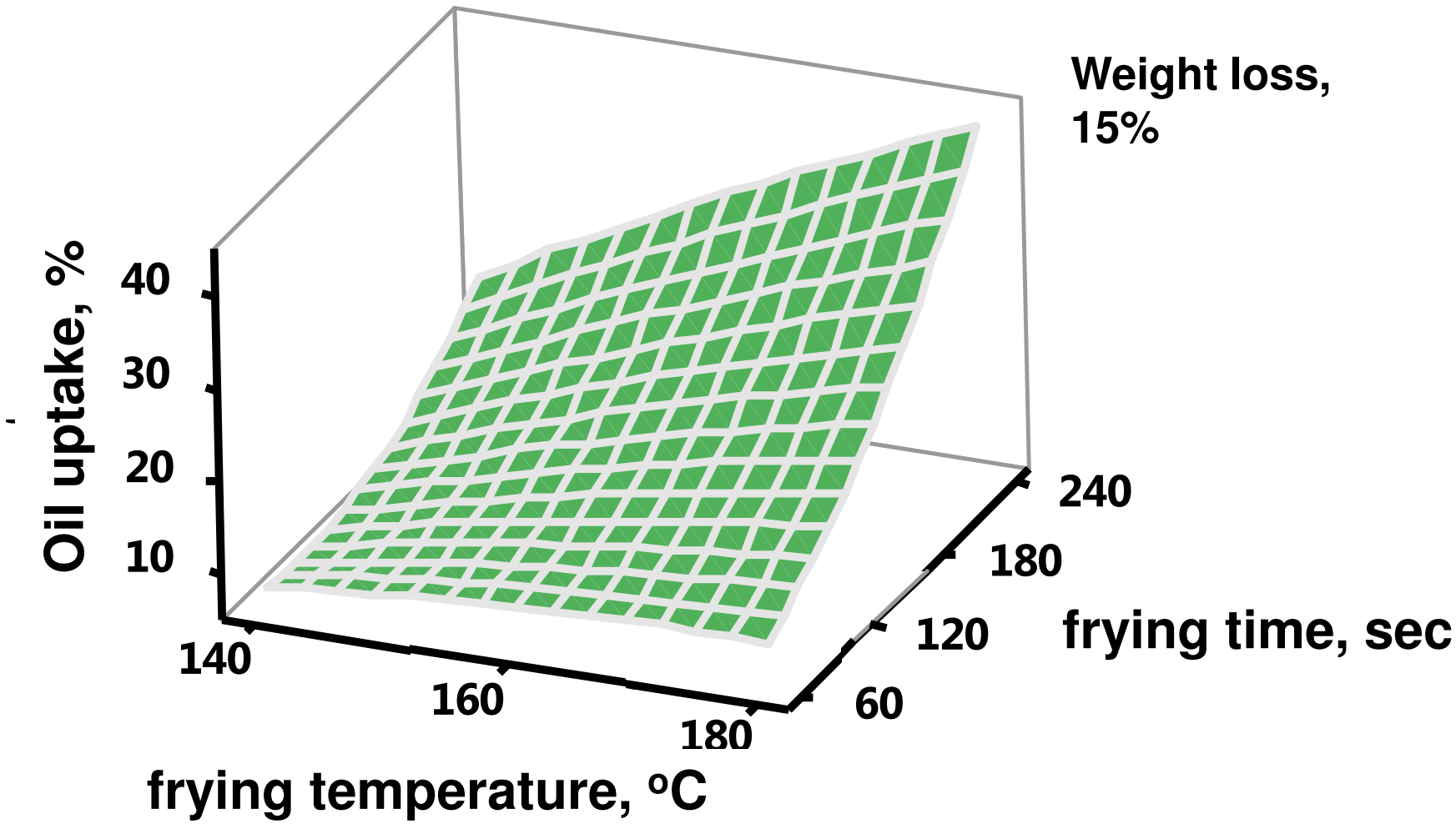

Figure 3. Change of oil uptake of carrot slices predried in a microwave and fried under effects of frying temperature and time

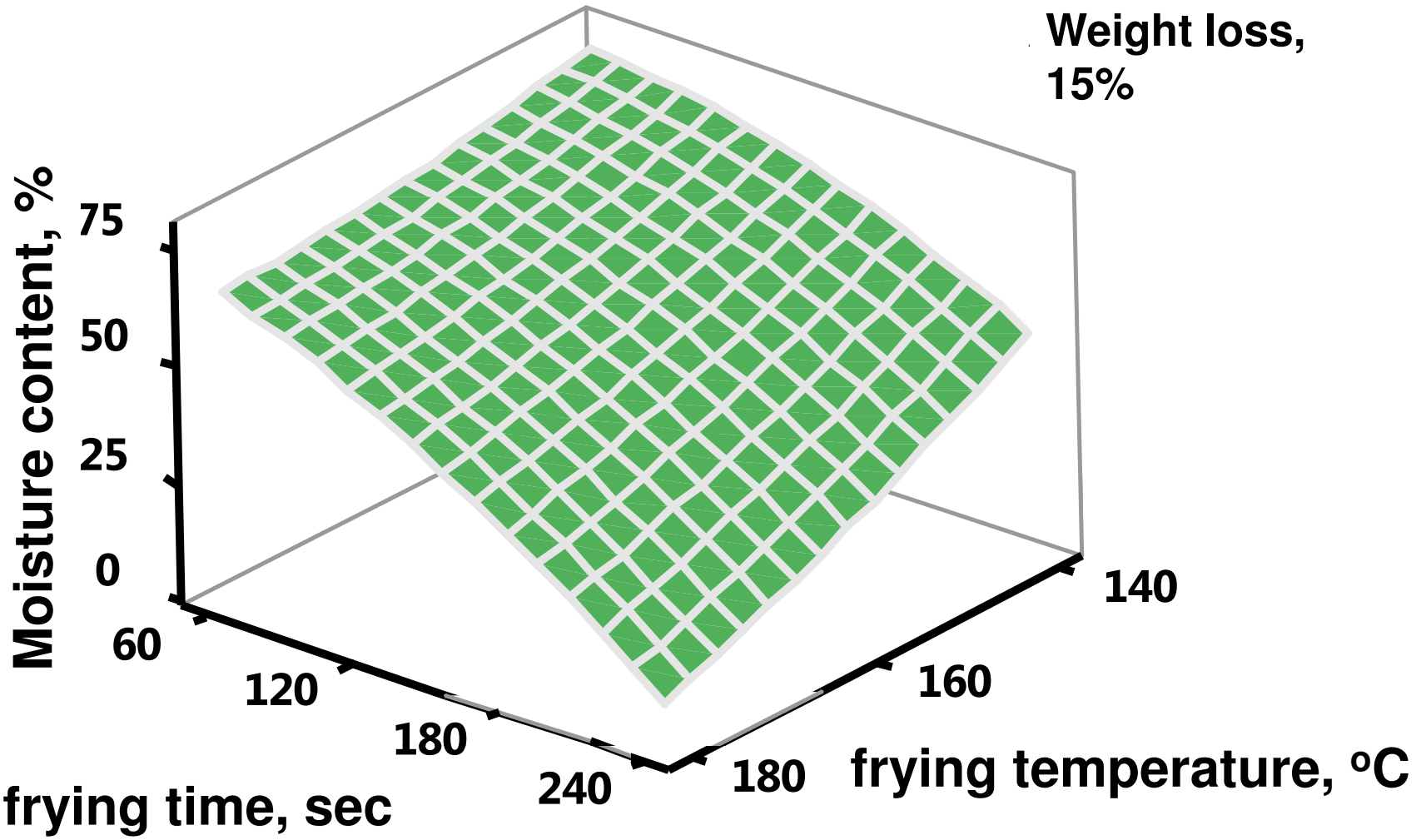

Figure 4. Change of moisture content of carrot slices predried in a microwave and fried under effects of frying temperature and time

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It could be suggested that

- Partial drying before frying is important pretreatment in terms of food characteristics.
- Oil uptake is one of them and mainly affected by frying conditions and partially predrying ones.
- Weight loss related to water removal during predrying is significant to control final oil uptake of fried carrot slice since a decrease in moisture content of frying material limits frying process, thus oil uptake.
- Direct influences of predrying conditions were not seen on oil uptake most probably due in part to the drying processes conducted at moderate conditions.

Acknowledgements

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Thank you for your attendances and attentions…

Your questions and/or comments