Study on Optimization of Microwave Frying of Potato Slices by Using Taguchi Design

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Abstract

Use of microwave fying for food products may be considered as a new way of improving the quality of the fried foods. In the first part of the study, the effects of microwaves on quality of fried potatoes (moisture content, oil content, color and hardness) were studied and the process was optimized by using Taguchi Technique. Microwave power level (400W, 600W & 800W), frying time (2.0, 2.5, 3.0 minutes) and oil type (sunflower, corn and ground nut oil) were the parameters used in the study. Moisture content of potatoes decreased whereas oil content, hardness and ΔE values of the potatoes increased with increasing frying time and microwave power level. The potatoes with the highest oil content were found to be the ones that were fried in the ground nut oil. The optimum condition was found as frying at 600W power level, for 2.5 minutes in sunflower oil.

Keywords: Microwave Frying; Optimization; Taguchi Technique.

1. Introduction

Deep-fat frying can be defined as the process of drying and cookingthrough contact with hot oil (Sahin, Sastry, &Bayindirli, 1999). It is widely used in preparation of foods, because the consumers prefer the taste, appearance and texture of fried food products (Rimac-Brnc˘ic´, Lelas, Rade, &Simundic, 2004). It is important that the deep-fat fried products should satisfy both health and sensory aspects of the consumer demand. High heat transfer rates are largely responsible for the development of desired sensorial properties in fried products (Hubbard&Farkas, 1999). Deep-fat fried products contain a substantial amount of oil since foods with low fat content absorb large amounts of oil during deep-fat frying. Oil absorption of the food is affected by many factors including process conditions (temperature, time), pre-treatment of the food (such as dehydration methods), physico-chemical characteristics of food, oil origin, chemical composition of oil and others. Longer times and lower frying temperatures usually lead to higher final oil contents in fried potato products (Saguy, Ufheil, & Livings, 1998).

The most commonly used oil for frying is the sunflower oil due to its high smoke point. Corn oil may also be an alternative for sunflower oil. In terms of fatty acid composition, sunflower oil contains around 48- 74% linoleic acid, where as that for corn oil is around 34- 65%. Linoleic acid is an essential multi-unsaturated fatty acid that cannot be synthesized in the human body, therefore should be definitely consumed externally, by food intake. Ground nut oil is also known to be very beneficial for human health. It is one of the rare nutrients, which possess the two important fatty acids oleic acid and linoleic acid in its combination.

2. Materials and methods

2.1. Materials:

Potatoes harvested from agricultural region were used in the experiments

2.1.1. Preparation of potato slices:

Potatoes were peeled, washed and cut by using a manually operated cutting device into disc shaped slices of 5 mm in thickness and 3.5 cm in diameter. The uniformity of thickness of slices was checked using a caliper. The slices were washed to remove free starch and surface was blotted with a paper towel before frying. Three different types of oil used in the study were sunflower oil , corn oil, and ground nut oil .

2.2. Methods:

2.2.1. Frying:

Microwave frying was conducted in a domestic microwave oven. Three power levels, 400 W, 600 W, 800 W were used in the experiments. Power levels were determined by IMPI 2-L test (Buffler, 1993) Microwave frying was performed using a glass container containing 400 ml oil. First, the oil which is at room temperature is heated to a temperature of 170^0 C at the maximum power level of the microwave oven (800 W). Then, potato slices were placed in hot oil and frying was performed at a specified microwave power and time. Seven pieces of potatoes were fried in each experiment. The oil was replaced after frying in three different conditions.

In addition to oil type and microwave power level, a third factor in the experimental design was the frying time. The potatoes were fried for 2.0, 2.5 and 3.0 min respectively.

As control, conventional deep-fat frying was conducted at a temperature of 170^0C in commercial bench-top deep-fat fryer (TEFAL, France) containing 400 ml sunflower oil. Samples were fried for 4.5 min. In both microwave and conventional deep-fat frying potato/oil ratio was kept the same at 0.0675 (w/v).

2.2.2. Orthogonal array and experimental parameters:

For Taguchi design and subsequent analysis, the software named as Qualitek-4 (Version 4.82.0) was used. The appropriate orthogonal array for the experiment was determined by the software. Since the interactions between the factors are also sought for, an L27 array was chosen by the program. This means that 27 experiments with different combinations of the factors should be conducted in order to study the main effects and interactions. It is important to note that the design is also a full factorial design (33 = 27). However, in general, Taguchi design is preferred since it reduces the number of experiments significantly. But in this study, since it is sought to observe all the interaction effects between the factors as well, the resulting Taguchi design became a full factorial design. Table 1 shows the 27 trial conditions to be performed. It is important to mention that the experiments were not conducted in the order described in Table 1. To provide randomness , experiments were performed depending

Table .1 Experimental design

Exp. no.	MW power	Frying time	Oil type
1	400	2.0	SF[a]
2	400	2.0	Corn
3	400	2.0	Nut
4	400	2.5	SF
5	400	2.5	Corn
6	400	2.5	Nut
7	400	3.0	SF
8	400	3.0	Corn
9	400	3.0	Nut
10	600	2.0	SF
11	600	2.0	Corn
12	600	2.0	Nut
13	600	2.5	SF
14	600	2.5	Corn
15	600	2.5	Nut
16	600	3.0	SF
17	600	3.0	Corn
18	600	3.0	Nut
19	800	2.0	SF
20	800	2.0	Corn
21	800	2.0	Nut
22	800	2.5	SF
23	800	2.5	Corn
24	800	2.5	Nut
25	800	3.0	SF
26	800	3.0	Corn
27	800	3.0	Nut

SF= Sun flower

3. RESULTS AND DISCUSSION

3.1 Effects of microwave frying on the quality parameters of potato slices

3.1.1 Moisture Content

The initial moisture content of potatoes was in the range 80-82% on wet basis (449.1 % db on average). It was observed that moisture loss of fried potatoes. Increased as power level and frying time increased for all types of oils (Fig. 4.1-4.3). The experimental data are available in Table .1 in Appendix.

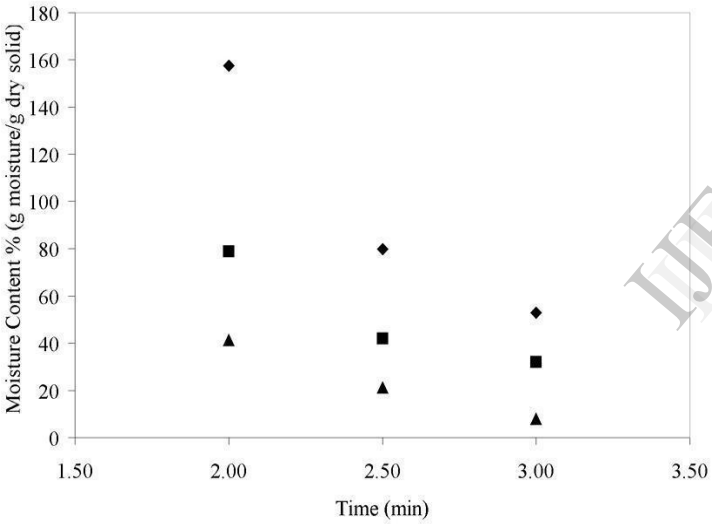

Figure.1-Variation of moisture content of potatoes fried in sunflower oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

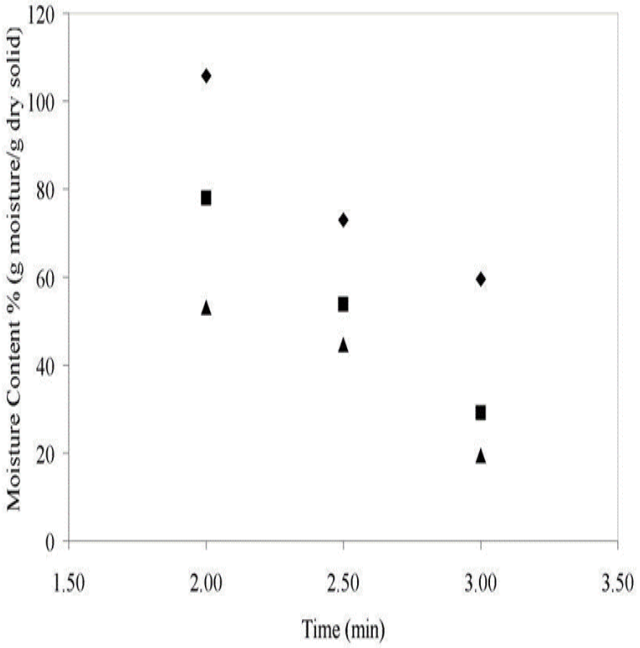

Figure.2-Variation of moisture content of potatoes fried in corn oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

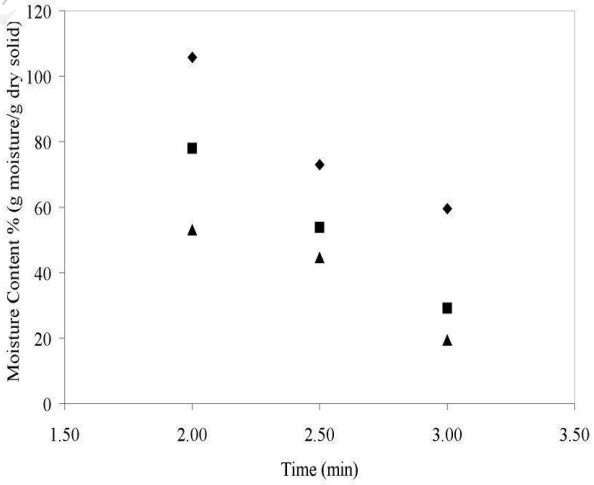

Figure.3-Variation of moisture content of potatoes fried in ground nut oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

3.1.2 Oil content

Oil content is one of the most important quality attributes of a deep-fat fried product. The texture of a low-oil-content product can be soft and unpleasant. However, the high oil content is costly to the processor and results in an oily and tasteless product **(Moreira, et. al, 1999).** Fig. 4-6 , show how oil content change with respect to frying time on the basis of microwave power levels for different oil types. It is common for the three oil type that as microwave power level and frying time increased the oil content of the fried samples increased. Foods with more moisture loss also show more oil uptake. Some even argue that the total volume of oil uptake will be equal to the total volume of water removed **(Pinthus,Weinberg and Saguy, 1993)**. Although microwave frying resulted in high moisture loss even at low power levels, lower oil uptake in microwave frying process was observed as compared to conventional frying.

For example, the oil content of potatoes fried at the lowest microwave power level, 400 W for 3 min were 25.48, 29.05, 68.98 % for sunflower, corn and ground nut oil respectively while it was 41.28 %, 37.22 %, 71.82 % for conventionally fried ones. In other words, microwave fried potatoes had lower oil contents compared to conventionally fried ones. The short frying time may be responsible for this. This may also be explained by the high evaporation rate of water compared to diffusion of oil into the potato due to pressure driven force that is generated by microwaves.

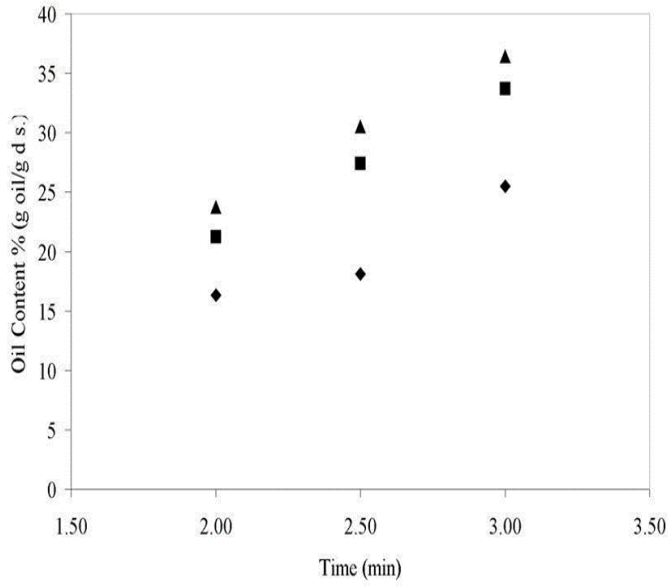

Figure.4- Variation of oil content of potatoes fried in sunflower oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

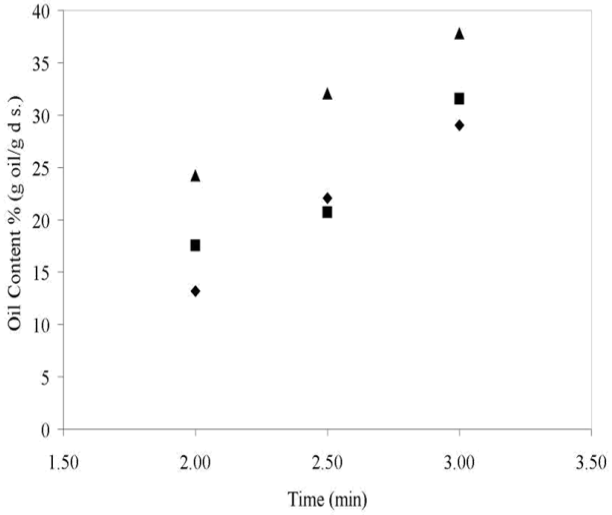

Figure.5- Variation of oil content of potatoes fried in corn oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

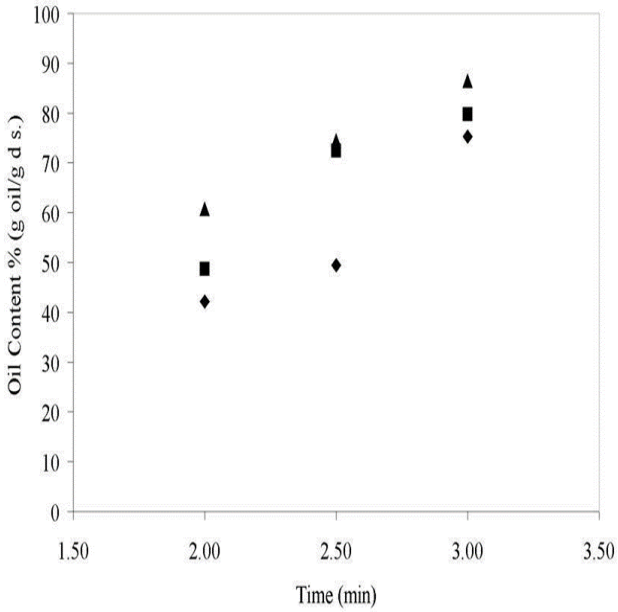

Figure.6- Variation of oil content of potatoes fried in ground nut oil with different microwave power levels: (♦) 400 W; (■) 600 W; (▲) 800 W

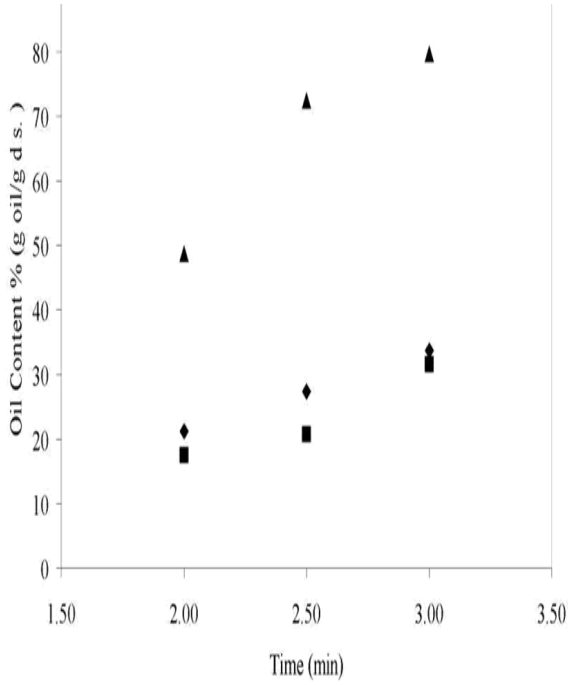

Figure .7 Variation of oil content of potatoes fried at the 600 W microwave power level in different oils. (♦) 400W; (■) 600 W; (▲) 800 W.

The above graph shows the effects of oil types on oil contents of potatoes fried at 600W microwave power level. Potatoes fried in the groundnut oil had significantly higher oil content than the ones fried in sunflower and corn oils. The same results were obtained in the other power levels as well. Therefore, it can be concluded that the potatoes fried in groundnut oil are far away from satisfying consumer's needs in terms of its high calorie

3.1.3 Color

The total color difference (ΔE) of potatoes increased as microwave power level and frying time increased. There were no significant difference between corn and sunflower oil whereas there was significant difference between groundnut oil.

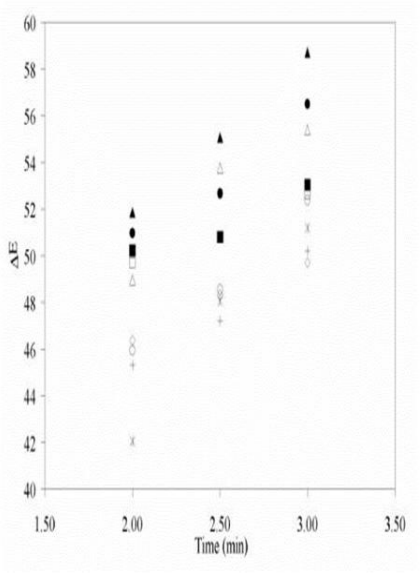

Figure .8 Variation of ΔE of the potatoes during frying at different microwave power levels and oil types. (■) 800W-Sunflower Oil; (▲) 800W- Corn Oil; (●), 800W-Nut Oil; ( ) 600W- Sunflower Oil; (Δ), 600W-Corn Oil; (O), 600W-Nut Oil; (*) 400W-Sunflower Oil; (◊) 400W-Corn Oil; (+) 400W-Nut Oil.

According to ANOVA results for the ΔE values it was seen that microwave power level, frying time and oil type are all significant in total color difference ($p<0.05$). Among the interactions, except the microwave power-oil type interaction, the other two way interactions and three way interactions were found to be insignificant ($p>0.05$). There were no significant difference between corn and sunflower oil whereas there was significant difference between nut oil and other oil types in terms of ΔE according to ANOVA test ($p<0.05$).

3.1.4 Texture

It can be seen that the hardness values increased with increasing frying time and microwave power level since as frying time and microwave power level increased, the moisture content decreased which resulted in harder products.

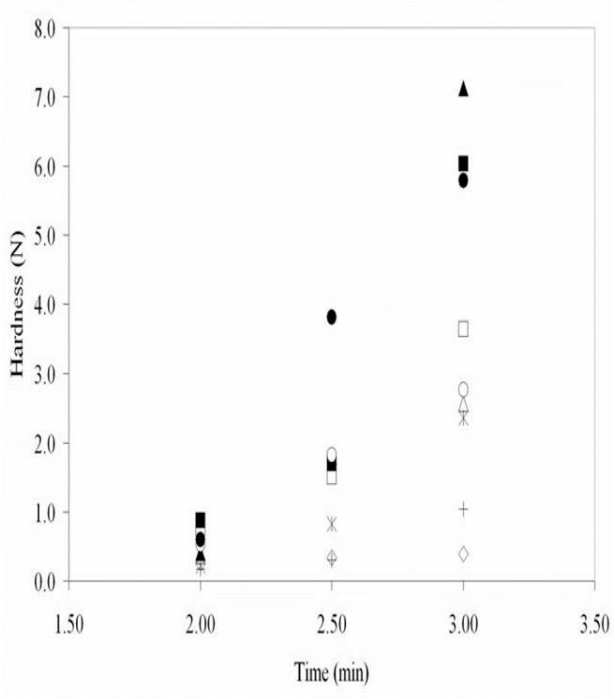

Figure.9 Variation of hardness of the potatoes during frying at different microwave power levels and oil types. (■) 800W-Sunflower Oil; (▲) 800W- Corn Oil; (●), 800W-Nut Oil; ( ) 600W- Sunflower Oil; (Δ), 600W-Corn Oil; (O), 600W-Nut Oil; (*) 400W-Sunflower Oil;(◊) 400W-Corn Oil; (+) 400W-Nut Oil.

3.1.5 Optimization

The optimum condition was found to be the medium microwave power level 600 W, 2.50 minutes frying time and the sunflower oil by Taguchi design. The values for the quality parameters obtained in the optimum condition of microwave frying process and conventional deep-fat frying. It should be mentioned that the microwave-fried potatoes had lower oil content than the conventionally fried ones. At the optimum condition microwave fried potatoes had similar ΔE and hardness values with conventionally fried ones.

4. Conclusion

It was possible to obtain fried potatoes with microwave, having similar colour and hardness values to that of conventionally fried ones. Although microwave frying decreased frying time and oil uptake significantly, microwave fried potatoes had more moisture loss as compared to conventionally fried ones. Oil content was smaller in microwave fried potatoes when sunflower or corn oils were used. Higher oil content was observed in the case of both microwave and conventionally fried potatoes when hazelnut oil was used a frying medium. Moisture content decreased but colour, hardness and oil content of potatoes increased as frying time and microwave power increased. Microwave power, frying time and oil type were found to be significant factors on affecting oil content, texture and colour of microwave fried potatoes. There was no significant difference between oil types on affecting moisture content of potatoes during frying. It was concluded that Taguchi technique could be a good way for optimization of microwave frying. It can be recommended to be used in other food processes as well.

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APPENDIX A

Microwave power level	Frying time(min)	Oil type	Moisture content(% db)	OilOil content(% db)db)	Color(ΔE) content(%	Color(ΔE)	Hardness (N)	Hardness (N)
400	2.00	Sunflower	0.56	1.61.6	41.8931	41.8931	0.21617	0.21617
400	2.50	Sunflower	0.51	1.81.8	43.401	43.401	0.82584	0.82584
400	3.00	Sunflower	0.44	2.52.5	46.0966	46.0966	2.36182	2.36182
600	2.00	Sunflower	0.51	2.12.1	44.3088	44.3088	0.76583	0.76583
600	2.50	Sunflower	0.43	2.72.7	45.5074	45.5074	1.51375	1.51375
600	3.00	Sunflower	0.35	3.33.3	46.7068	46.7068	3.63546	3.63546
800	2.00	Sunflower	0.35	2.32.3	44.5596	44.5596	0.87768	0.87768
800	2.50	Sunflower	0.31	3.13.1	46.3555	46.3555	1.70304	1.70304
800	3.00	Sunflower	0.20	3.63.6	48.3228	48.3228	6.03219	6.03219
400	2.00	Corn	0.54	1.31.3	49.6999	49.6999	0.25071	0.25071
400	2.50	Corn	0.52	2.22.2	48.9551	48.9551	0.33706	0.33706
400	3.00	Corn	0.49	2.92.9	53.7255	53.7255	0.39016	0.39016
600	2.00	Corn	0.46	1.71.7	55.3844	55.3844	0.36569	0.36569
600	2.50	Corn	0.47	2.12.1	51.8394	51.8394	1.79704	1.79704
600	3.00	Corn	0.44	3.13.1	55.0365	55.0365	2.56430	2.56430
800	2.00	Corn	0.40	2.42.4	58.6973	58.6973	0.40741	0.40741
800	2.50	Corn	0.38	3.23.2	45.2954	45.2954	1.80722	1.80722
800	3.00	Corn	0.38	3.73.7	47.195	47.195	7.12644	7.12644
400	2.00	Groundnut	0.56	4.14.1	50.1922	50.1922	0.17574	0.17574
400	2.50	Groundnut	0.52	4.84.8	45.9422	45.9422	0.30548	0.30548
400	3.00	Groundnut	0.50	6.06.0	48.5248	48.5248	1.04345	1.04345
600	2.00	Groundnut	0.49	4.74.7	52.3723	52.3723	0.53048	0.53048
600	2.50	Groundnut	0.47	6.76.7	50.9624	50.9624	1.82274	1.82274
600	3.00	Groundnut	0.45	6.86.8	52.3723	52.3723	2.76624	2.76624
800	2.00	Groundnut	0.40	7.57.5	50.9624	50.9624	0.59659	0.59659
800	2.50	Groundnut	0.39	7.87.8	52.6591	52.6591	3.80956	3.80956
800	3.00	Groundnut	0.36	9.09.0	56.4479	56.4479	5.7	5.7