QUALITY ATTRIBUTES OF SPRING ROLL DURING FRYING IN AIR FRYER OVEN

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Abstract

The objective of the present study was to determine the effect of air fryer technology on quality changes of spring roll during frying in an oven by means of color values (L, a*, b*), browning index (BI) and frying efficiency. Box-Behnken design was carried out for oven temperature of 200 to 240 °C, a frying time of 15 to 20 min, and tray rack position in oven of 1 to 3. L* values ranged from 47.29 to 82.34. BI values ranged from 27.10 to 160.30 for spring rolls fried in air fryer oven. The highest coefficients of correlation (r=0.99) were determined to be between L* and BI values. The minimum BI value was observed at 200 °C for 18 min with the tray placed on the third rack position. The oven temperature, frying time, and tray rack position played the most crucial role in BI, given the high F-values (77.41, 75.24, 76.41, respectively) and very low p-values (0.000) ($p < 0.05$). The R^2 value of 0.95 and R^2_{pred} of 0.89 were found for the air fryer frying of spring rolls. These results suggested that frying with air fryer of spring rolls can be used for maintaining the quality of spring rolls.*

Keywords: *air fryer oven, spring roll, color, browning*

1. INTRODUCTION

Obesity, which is common among children, adolescents, and adults, has become one of the most serious public health problems in the 21st century. The prevalence of childhood obesity in the world has increased significantly in the last 3 years. The alarming increase in the incidence of child and adolescent obesity in the world increases the risk of co-morbidities (cardiovascular disease, Type 2 diabetes mellitus, metabolic syndrome, non-alcoholic fatty liver disease, osteoarthritis, obstructive sleep apnea syndrome, some types of cancer) has also increased. According to the Turkish Nutrition and Health Survey data, 8.2% of children and adolescents aged 6-18 were considered obese, and 14.3% were overweight (TBSA, 2019). Due to the obesity problem, there is an increase in awareness about healthy nutrition, and it is observed that consumers' interests in natural foods as well as foods cooked in healthy conditions have also increased. Foods produced with innovative cooking technologies are important to expand the market potential of healthy nutrition for the whole society.

Frying is widely used in a traditional cooking process which concerns the transfer of heat between the food and the hot oils (Choe and Min, 2007). Fried products are often preferred because of their sensory properties such as taste and smell (Fikry et al., 2021). However, these foods are known to be harmful to health due to their high fat content and low nutritional value. It has been proven that polar compounds formed in fried foods cause chronic diseases, hypertension, and endothelial dysfunction, especially in the cardiovascular system (Zaghi et al., 2019). Additionally, obesity and gastrointestinal disorders are more prevalent in people who consume fried foods (Rangel- Zuñiga et al., 2016; Ekhator et al., 2018). Healthier cooking methods are being explored to provide similar sensory properties due to adverse health effects. Hot air frying (air fryer), which has been used recently, is one of them (Teruel et al., 2015). Oil content of the products cooked by air fryer are reduced without losing their product quality and oxidative deterioration of lipids in these products are also reduced (Tian et al., 2017).

An air fryer has a heating system and a powerful mechanical fan to circulate hot air, like a convection oven. Air fryers fry foods that are browned and crispy outside, moist and tender inside and use minimal or no oil. Today, air fryers on the market come in two basic styles: 1) air fryers with cooking baskets, and 2) regular ovens with an air fryer convection feature. Air fryers with cooking baskets have smaller capacity compared to air fryer ovens. Both air fryers have shorter cooking time and produce healthier and low-calorie foods (Boz 2022; Fabre et al., 2018).

In the literature, there are a few studies on air fryer frying (Santos et al., 2017; Zaghi et al., 2019). To the best of our knowledge, there is no study on frying spring rolls using an air fryer oven. The aim of our study was to determine the best frying temperature, frying time and tray rack position for spring rolls based on color parameters, browning index, and sensory attributes using Box-Behnken Response Surface Methodology (RSM).

2. MATERIALS AND METHODS

2.1. Materials

Pastry sheets and curd cheese were purchased from a local market in İzmir, Turkey. A commercial air fryer oven was provided by Vestel White Goods Company, Cooking Appliances Factory (Manisa, Turkey).

2.2. Spring Roll Preparation

Pastry sheets were cut in predetermined dimensions (10 cm width) and approximately 10-12 g curd cheese was placed on the top part of the sheet and rolled.

2.3. Spring Roll Frying

A commercial air fryer oven (Vestel) was employed to fry the spring rolls. The non-fried (raw) spring rolls were used as the control group. Frying temperature (200, 220, and 240 °C), frying time (15, 18, and 20 min), and tray rack position (1, 3, and 5 from bottom) were the parameters used in Box-Behnken Response Surface Methodology. The experiments were conducted in 13 conditions by using these three different parameters. While frying, the tray, spring roll samples placed, were rotated in the middle of total frying time. At the end of the frying process, spring roll samples were cooled down to room temperature for further analysis.

2.4. Analyses for Fried Spring Rolls

2.4. 1. Frying Yield

Frying yield was determined by weighing the raw and fried spring rolls, and calculated according to the equation given below (Vitrac et al., 2000):

$$Frying\ yield(\%) = \frac{B}{C} * 100$$

where the weight of the raw spring rolls (C), the weight of the fried spring rolls (B).

2.4. 2. Color analyses

2.4.2.1. Color Analysis using Colorimeter

The color values (CIE L*(Lightness), a*(redness-greenness), and b*(yellowness-blueness)) of spring rolls were determined by using a Minolta colorimeter (Konica Minolta Sensing Inc., Japan). Measurements were taken for spring roll samples fried at each of the Box-Behnken design (BBD) points and 3 readings at different positions were taken from each sample. CIE *L*, a*, b** values of samples were analyzed, and total color difference (ΔE) of samples and browning index (BI) were calculated from the *L*, a* and b** values as follows:

$$\Delta E = \sqrt{(L_0 - L^*)^2 + (a_0 - a^*)^2 + (b_0 - b^*)^2}$$

where subscript ‘0’ refers to the color value of control (raw) sample.

$$BI = \frac{100(x - 0.31)}{0.17}$$

where x;

$$x = \frac{(a^* + 1.75^* L)}{(5.645L^* + a^* - 0.012b^*)}$$

2.4.2.2. Color Analysis using Machine Vision System

A color image for spring roll samples at each BBD design point was obtained with a digital camera (Nikon D90, Thailand) under controlled and defined illumination conditions (D65 illumination in a light box described by Luzuriaga et al., 1997) and analyzed by using a LensEye software (Gainesville, FL, USA). The software identifies every pixel in an image that has color attributes (R, G, B, L*, a*, b, hue, saturation, intensity) lower than, or higher than a given threshold, or attributes between two threshold values. When these pixels are identified and counted, their percentage based on the object's total view area is calculated.

2.5. Modeling and optimization

Box-Behnken design (BBD) is a statistical tool used to develop a quadratic model to predict color value (L*, a*, b*) and browning index (BI) during air frying as a function of frying temperature (200, 220 and 240 °C), frying time (15, 18 and 20 min) and tray rack position (1, 3, and 5 from bottom) (Table 1). The levels of these factors were determined by initial experiments.

Table 1. (Un)coded variables of Box-Behnken design of frying conditions for color parameters and BI value

Code	Temperature (°C)	Time (min)	Tray rack Position
AF-C-1	200 (-1)	18 (0)	1 (-1)
AF-C-2	240 (+1)	20 (+1)	3 (0)
AF-C-3	220 (0)	15 (-1)	1 (-1)
AF-C-4	220 (0)	20 (+1)	1 (-1)
AF-C-5	240 (+1)	18 (0)	1 (-1)
AF-C-6	220 (0)	20 (+1)	5 (+1)
AF-C-7	240 (+1)	18 (0)	5 (+1)
AF-C-8	220 (0)	15 (-1)	5 (+1)
AF-C-9	220 (0)	18 (0)	3 (0)
AF-C-10	200 (-1)	18 (0)	5 (+1)
AF-C-11	200 (-1)	15 (-1)	3 (0)
AF-C-12	240 (+1)	15 (-1)	3 (0)
AF-C-13	200 (-1)	20 (+1)	3 (0)

All statistical analyses were performed using MINITAB 16.0 (Minitab Inc., State College, PA, USA). Analysis of variance (ANOVA) and regression models were performed at the 95% confidence interval ($p<0.05$) to define significant terms of the estimation model. Additional experiments, to validate the models, were carried out under the optimal conditions. Verification of the predicted model was conducted by the coefficient of variation (CV, %) as follows:

$$CV = \frac{\sigma}{\overline{X}} * 100$$

where is σ sample standard deviation, and $\overline{X}$ is sample mean.

2.6. Sensory Analysis

For sensory analysis, one set of spring rolls was fried in the air fryer oven using the tray designed for air fryer and air fryer features. The other set of spring rolls was baked in the same oven without using the air fryer features and using the regular tray used for the oven. The frying/baking temperature, time and tray rack position were selected as BBD design optimum conditions which were 240 °C, 20 min, 5th rack position. The effect of cooking in the air fryer oven and regular oven on sensory attributes (color, appearance, odor, crispness, taste, overall acceptability) of spring rolls was analyzed. The samples were scored by untrained panel of 51 panelists (researchers and undergraduate/graduate students) from Izmir Institute of Technology (İzmir, Turkey) using a 5-point scale. The different values in the scale indicated as 1: dislike extremely, 2: dislike very much, 3: neither dislike nor like, 4: like very much and 5: like extremely.

3. RESULTS AND DISCUSSION

It is known that high frying yield (%) value indicates lower weight loss. According to the Fig. 1, it was observed that the highest frying yield, 93%, was obtained in AF-C3 which corresponds to the conditions of 220 °C, 15 min, and 1st tray rack position. On the other hand, the lowest frying yield was obtained in AF-C7 corresponds to the conditions of 240 °C, 18 min, and 5th tray rack position. The low yield could be related to the high temperature and long frying time.

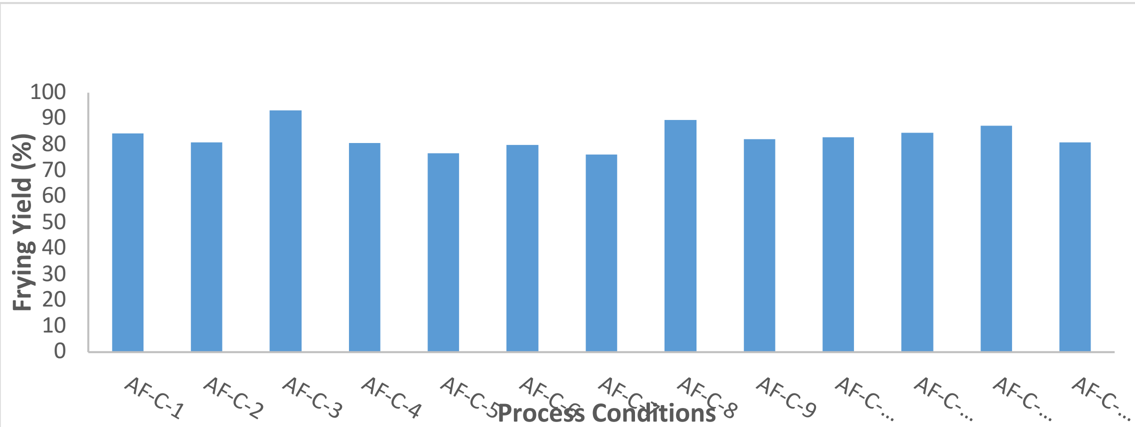

Fig. 1. Frying yield (%) of each spring roll under different air fryer conditions

The relations of color attributes with browning index (BI) have been evaluated in Fig 2. The lower the $L*$ value and the higher the $b*$ value, the browning index value was higher. For instance, at AF-C-7, the spring rolls were fried at 240 °C for 18 min at the 5th tray rack position, the browning index value was observed as the highest value which was 160.3. Also at this frying condition, the $L*$ value of the spring rolls was lower and the $b*$ value was higher than the most of spring rolls fried at other conditions. There is a good correlation between BI and ΔE (R^2=0.99). According to ANOVA results, frying temperature, frying time and tray rack position showed significant main effects ($p<0.05$) on $b*$ value. Only frying temperature and frying time positively affected the $b*$ value, whereas only frying time and tray rack position had a negative effect on the $b*$ value. The predicted model was adequate, possessing no significant lack-of-fit (p=0.081>0.05) and very satisfactory R^2 values (R^2=0.89, R^2_{adj}=0.84, R^2_{pred}=0.77).

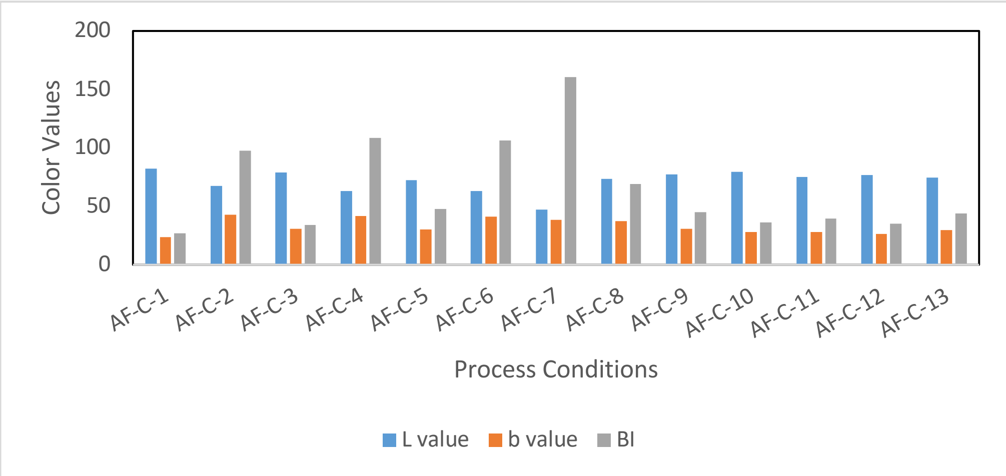

Fig. 2. Color attributes and BI values of spring rolls at different air fryer conditions

For better understanding of variables, the response surface plots for b^* value are plotted as shown in Fig. 3. The b^* value increased with the increased time under the highest tray rack position at an increasing rate (Fig. 3a). The b^* value increased with the decreased temperature under the highest tray rack position at an increasing rate (Fig. 3b). The b^* value peaked with the temperature (240 °C) at the longest frying time (20 min) (Fig. 3c).

The optimum conditions for b^* value of spring rolls predicted by the model were obtained as frying temperature of 240 °C, frying time of 20 min and the 5th tray rack position, which also estimate the b^* value of 48.4. The experimental b^* value under these circumstances was measured as 40.86. Thus, the low value of coefficient of variation determined to be 11%, satisfies the better reproducibility of the model.

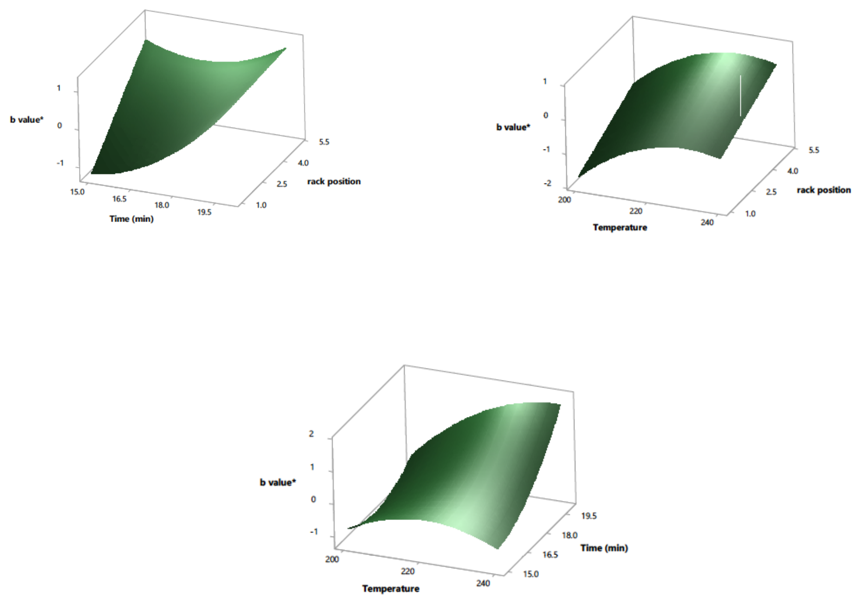

Fig. 3. Response surface plot for b^* value a) the effects of frying time and tray rack position, b) frying temperature and tray rack position, c) frying temperature and frying time

For spring roll samples in Fig. 4, the percentage of the total area of each sample that has pixels with a* values greater than 5 is shown in Table 2. The percentage of the total area of the samples that has pixels with a* values greater than 5 increases as the frying temperature and time increase and at higher tray rack positions. The spring roll sample fried at optimum condition had the highest percentage of redness of the total area.

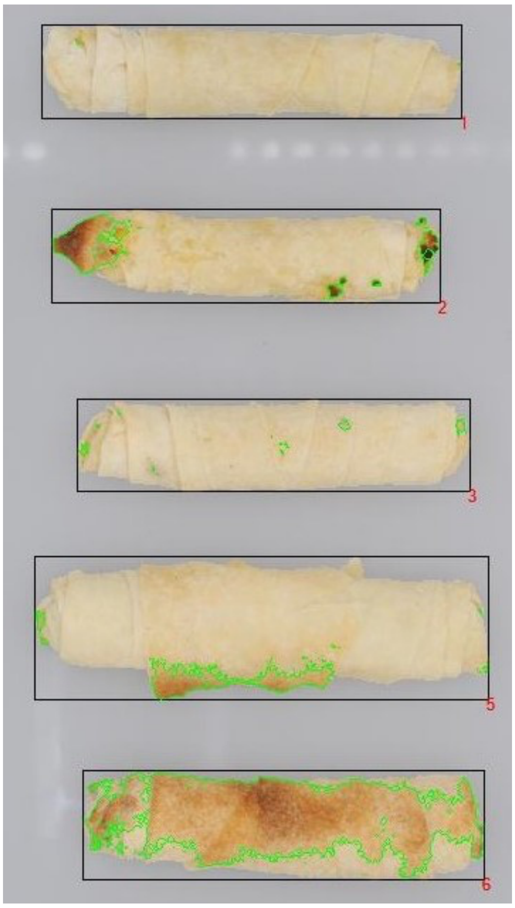

Fig. 4. Regions of spring roll samples fried at 200 °C (1, 2, 3,5) and the optimum condition (6) with a* values greater than 5 are presented with a green border

Table 2. Percent area with a* greater than 5 for spring rolls fried at frying temperatures, frying times and tray rack positions

Frying temp (C)	Tray rack position	Frying time (min)		
		15	18	20
200	1		7.37	
	3	0.06		
	3			1.26
	5		13.06	
220	1	9.63		
	1			8.38
	3		12.35	

	5	1.61		
	5			1.31
240	1		14.58	
	3	37.99		
	3			71.84
	5		20.09	
	5*			72.7

*Optimum frying conditions

As a result of sensory analysis, no significant difference was observed in other sensory attributes except odor (Fig. 5). This difference in odor could be due to the Maillard reaction, especially on the surface of the spring roll. In addition, different cooking techniques (air fryer oven and regular oven) are an important factor in the realization of this reaction (Martins et al., 2000). A total of 26 panelists preferred spring rolls fried in the air fryer oven, and 25 panelists preferred the spring rolls baked in the regular oven.

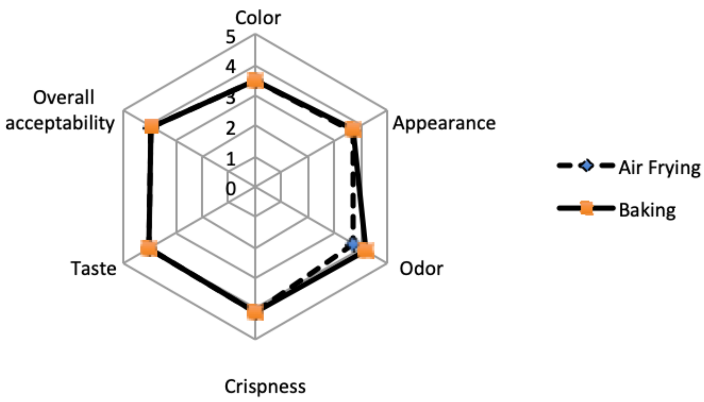

Fig. 5. Sensory analysis of spring rolls fried in air fryer oven and baked in regular oven

4. CONCLUSIONS

Among the three frying parameters, frying time was observed to be the most significant parameter, while the tray rack position had a negligible effect. The temperature profile in the air fryer oven needs to be recorded and if needed adjusted to avoid the rotation of the tray in the middle of frying which causes a heat loss during frying as well as to predict the color changes on the surface of the spring rolls during frying more precisely. There was no significant difference between the air fryer oven and the regular oven in terms of taste, crispiness, and appearance attributes of the fried spring rolls. As a conclusion, spring rolls fried in air fryer oven was liked more than the spring rolls baked in the regular oven.

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