Consumer Acceptability and Quality Evaluation of Potato Strips Baked in a Radiant Wall Oven

Bilal Kirmaci, Rakesh K. Singh and Robert L. Shewfelt
Department of Food Science and Technology, The University of Georgia, Athens, Georgia 30605, USA

Abstract

Instrumental and sensory quality of potato strips baked in a Radiant Wall Oven (RWO) was evaluated and compared to deep-fat fried and conventional oven (CO) baked samples. Even though RWO baked potato strips had one-fourth the fat content of the deep-fat fried samples, there was no significant difference in firmness, puncture force, and chroma of RWO baked and deep-fat fried samples. Consumer acceptability of RWO baked potato strips was 65.7% and 85.7% before and after revealing the nutrition facts, respectively. Both were lower than acceptability of deep-fat fried samples. However, 36.5% of consumers were willing to purchase RWO baked samples.

Keywords: Color, infrared heating, sensory, texture.

1. Introduction

French fries are very popular food, and served at any fast food restaurant. Quality of the potato strips includes golden yellow color, crispy crust, mealy core and oil content. Color of the potato strips is enhanced due to Maillard reaction between reducing sugar and amino acid of the product during heating. Reducing sugars are seen as the most contributor to the color enhancement of the fried potato strips [1].

The other quality characteristic of a potato strip is its texture. Crispiness is a texture attribute that is related to the total number of fractures occurring during deformation of the food. Crispiness of a food product can be evaluated by instrumental analysis, as well as sensory analysis. Different kinds of instrumental methods used to evaluate the crispiness have been reviewed by Miranda and Aguilera [2]. Puncture test with a probe (1 – 3 mm) assesses surface of the fried products. This test can give information about springiness of the product, toughness of the crust and softness of the core [3]. Kramer shear or knife blade shear tests are used to determine the firmness (hardness) of the potato strips.

Commercially available French fries have 12.5 – 15.5 % oil content on wet basis [4]. As amount of fat in the diet has become a concern, efforts to reduce the oil content of fried products were started [5]. Infrared (IR) heating was studied to reduce the fat content of the potato strips. Weaver and Huxsoll [6] suggested to improve crispiness and lower oil content by pre-drying potato strips prior to blanching. Furthermore, Lloyd et al. [7] proposed an IR processing as an alternative to deep-fat frying by quartz halogen radiant emitters. Recently, Bingol et al. [8] used IR heating to reduce fat uptake of French fries during blanching.

Kirmaci and Singh [4] also suggested to bake potato strips in an IR based Radiant Wall Oven (RWO) at 365 °C for 6.5 min. They reported that RWO baked potato strips had comparable quality to the deep-fat fried samples. They stated that trained panel also verified the similar texture in both RWO baked and deep-fat fried potato strips. Trained panel, however, cannot be correlated to consumer acceptability. Therefore, they suggested to investigate consumer acceptability of the RWO baked potato strips at 365 °C for 6.5 min. Objectives of this study were (i) to instrumentally measure and compare color and texture of RWO baked, conventional oven baked and deep-fat fried potato strips, and (ii) to evaluate and compare consumer acceptability and willingness to purchase of RWO baked potato strips to deep-fat fried and conventional oven baked samples.
2. Materials and methods

2.1. Sample Preparation
Forty five boxes (0.9 kg) of par-fried frozen potato strips (Great Value - Regular Cut French Fries, Walmart Inc., Bentonville, AR) were purchased from a national supermarket and stored in walk-in freezer at -40 °C. Par-fried frozen potato strips were sorted to have approximately 1 cm in width and 1 cm thickness. The sorted potato strips were cut to have 5 cm length, and then, stored in a freezer at -20 °C prior to further processing. Three different processes, described below, were conducted in triplicate. Baked/fried potato strips were placed on a food warmer (Model No. GRFFB, Hatco Corp., Milwaukee, WI) having 500 W infrared heat lamp and 250 W base heating element. Samples stayed for 2 min on the food warmer to control the temperature of the samples before color and texture analysis. Samples that stayed for more than 5 min on the food warmer were discarded.

2.2. RWO processing
Potato strips were baked in a radiant wall oven (Pyramid Food Processing Equipment Manufacturing Inc., RWO-12-36, Tewksbury, MA) at 365 °C for 6.5 min, as described by Kirmaci and Singh [4]. RWO was heated by combustion of natural gas. Heated stainless alloy elliptical tube wall emitted infrared radiation to potato strips that were placed on the perforated conveyor belt (0.3 x 1.2 m). In addition to radiation, conduction also contributed to the heating mechanism, since belt was also heated by the oven. Baked potato strips were placed in a warm stainless steel pan, and then, transferred immediately to the food warmer.

2.3. Deep-fat frying
Potato strips were fried at 177 °C for 3 min with 5 L peanut oil in a deep-fat fryer. Oil was discarded after 10 h of usage. Excessive oil on the fried potato strips was drained on a piece of paper towel placed on a ceramic plate, and then, strips were immediately placed in a stainless steel pan on the food warmer.

2.4. CO baking
Potato strips were baked on an aluminum baking sheet (Naturals Baker's Half Sheet, Nordic Ware, Minneapolis, MN) in a conventional oven (GE Profile, General Electric Company, Fairfield, CT) at 204 °C for 20 min, as suggested by the manufacturer. Baked strips were placed on a warm stainless steel pan, and then, immediately transferred to the food warmer.

2.5. Temperature Monitoring
Temperatures of center and underneath the surface of the potato strips were monitored by Teflon (Polytetrafluoroethylene - PTFE) coated type T thermocouples (Omega Engineering Inc., Stamford, CT) with a portable data logger (RDXL100, Omega Engineering Inc., Stamford, CT). Temperature of the wall in RWO was measured by type K thermocouple (Omega Engineering Inc., Stamford, CT). Furthermore, temperatures of the oil in the deep-fat fryer, temperature of the air in the RWO and conventional oven were measured by the same type of thermocouple. A thermocouple was inserted to the product after piercing the potato strips by a hypodermic needle.

2.6. Shrinkage
Width and thickness of the middle of the potato strips before and after each processing were measured by a caliper. Percent difference in area, calculated by multiplying width with thickness, of each potato strip before and after processing was reported as deformation in shape.

2.7. Moisture and fat content
Moisture content of the baked potato strips was determined by vacuum oven method of the Association of Official Analytical Chemists (AOAC, 1995). About 2-3 g samples placed in pre-dried thimbles made from No.1 Whatman Paper, and then, dried in a vacuum oven (Cole-Parmer Instrument Co., Vernon Hills, IL) at above 40 kPa vacuum at 70 °C for 24 h.

The fat content of the baked potato strips was measured by the Soxhlet method (AOAC, 1995). Samples that were dried for moisture content analysis were placed in Soxhlet to extract oil with petroleum ether for 8 h in a Pyrex
Distillation Unit. Fat content was gravimetrically calculated after removal of solvent from samples, and it was reported as percentage of oil per total solids of potato strips.

2.8. Texture – Firmness
Firmness of the potato strip samples was determined by the Texture Analyzer (TA.XT2i, Stable Micro Systems Ltd., Hamilton, MA) with chisel knife blade attachment. For each treatment, 5 baked potato strips, adjacent to each other, were placed on the slotted base to cover the area. Width and thickness of the potato strips were also measured by a caliper. A 5-kg load cell was used to detect maximum necessary amount of force exerted on the sample to divide the samples into halves. Pre-test cross arm speed was 1.5 mm/s and test speed was 2 mm/s. Texture Analyzer was calibrated prior to the test. Three measurements were taken for each replication.

2.9. Texture – Puncture Force
Surface of the potato strip was evaluated by the Texture Analyzer (TA.XT2i, Stable Micro Systems Ltd., Hamilton, MA) with 3 mm puncture probe for each nine strips. Thickness of the potato strips was measured by a caliper. Pre-test cross arm speed was 1.5 mm/s and test speed was 2 mm/s. Probe was allowed to travel 6 mm after touching the sample, and, peak force was reported as puncture force.

2.10. Color
Color of the potato strips samples was measured by a colorimeter (model CR-410, Konica Minolta Sensing Inc., Ramsey, NJ). Color measurements were taken, after calibration with a white standard calibration cap. CIE color space was used to quantify the color of the samples in which lightness (L), chroma (saturation or brightness) and hue angle (°) were determined. Nine potato strips were placed adjacent to each other, and, color was measured, as colorimeter averaged three readings for a single measurement. As baking altered the color of the bottom surface of the potato strip, both top and bottom surface of the strips were measured. In the case of deep-fat frying, color of the two opposite surfaces was measured. A total of six measurements were taken for each replication.

2.11. Consumer Acceptability
Consumer acceptability test and willingness to purchase potato strip samples were evaluated by sensory analysis. Over one hundred individuals at the University of Georgia served as sensory panelists. All panels were conducted at the sensory laboratory in the Department of Food Science and Technology over a three-day period. White lighting was used throughout the evaluation sessions and sensory booths had positive air flow to prevent any aroma circulation from the sample preparation area. Three pieces of processed potato strip samples were placed in a 3-digit coded paper sample cup for each treatment, and then were served to the panelists immediately. Water at room temperature and unsalted top saltine crackers were used as palate cleansers between samples.

First, panelists read and signed the consent form stating that voluntarily participating in the sensory test. Then, panelists were asked to evaluate the samples in terms of overall acceptability in pre-determined order. The order of sample evaluation was designed according to randomized. Panelists recorded their evaluation on a 3 point structured hedonic scale labeled as “superior”, “acceptable” and “unacceptable” for each samples. Panelists marked their willingness to purchase on the 5-point scale, labeled as “definitely would buy”, “probably would buy”, “might or might not buy”, “probably would not buy”, and “definitely would not buy”. At the end of the analysis, nutrition fact and total calorie of the RWO baked and deep-fat fried samples were revealed to each panelist. Then, each panelist was again asked about the acceptability of the RWO baked samples. Total frequency of “superior” and “acceptable” was reported as acceptability of the samples. Total frequency of “definitely would buy” and “probably would buy” choices were reported as willingness to purchase. Total percentage of acceptability was also reported after revealing the nutrition facts.

2.12. Statistical Analysis
Each treatment was replicated three times, and the order of treatments was randomized. One-way analysis of variance (ANOVA) was used to analyze the data using SAS (9.3, SAS Institute Inc., Cary, NC). Means were separated by Tukey’s test at 95% confidence level. Frequency of the consumer acceptability and willingness to purchase data was determined using Microsoft Office Excel 2007 (Microsoft Corp., Redmond, WA).
3. Results and discussion

3.1. Processing conditions
Heating rates of the deep-fat fryer, RWO and CO for underneath the surface of the potato strip were 87.4, 34.1, and, 10.2 °C/min, respectively. Heating rates of center of the potato strip in the deep-fat fryer, RWO and CO were 73.5, 31.1, and, 10.6 °C/min, respectively. The highest heating rate was observed in deep-fat fryer and the lowest was occurred in CO.

Potato strips were baked at 369.8 ± 5.04 °C for 6.6 ± 0.16 min in RWO. The variation in the processing time in RWO was due to variation in the belt speed. In deep-fat fryer, potato strips were fried at 177.8 ± 2.15 °C for 3 min. Potato strips were baked at 206.1 ± 15.83 °C in the CO for 20 min.

3.2. Shrinkage
All of three treatments caused shrinkage. Deep-fat fried potato strips retained their original size the most among other treatments, by losing 14.2±5.36% of their dimensions. The highest deformation occurred in CO baking. It caused potato strips to lose 29.3±7.12% of their original dimensions. Whereas, shrinkage in RWO baked potato strips was 20.4±4.53% of their original dimensions.

3.3. Moisture and fat content

Moisture content of the RWO baked, CO baked and deep-fat fried potato strips were 69.34 ± 1.16%, 61.82 ± 2.21% and 59.52 ± 2.45% on wet basis, respectively. Moisture content of the RWO baked potato strips was significantly (p<0.0001) higher than that of deep-fat fried and CO baked samples. Whereas, moisture content of the CO baked potato strips was not significantly different than that of deep-fat fried samples.

The fat content of the RWO baked, CO baked and deep-fat fried potato strips were 7.03 ± 0.55, 6.90 ± 0.89, and 29.65 ± 0.77 g fat per 100 g dry solids, respectively. Deep-fat fried potato strips had the highest fat content. It was more than four times of the fat content of RWO and CO baked samples. There was no significant difference between fat content of the RWO and CO baked potato strips.

3.4. Texture

Maximum peak force of all three treatments for firmness and puncture tests are given in Table 1. CO baked potato strips had the firmest (p<0.01) texture among three treatments. Whereas, firmness of the potato strips baked in RWO was not significantly different than that of deep-fat fried samples. However, Kramer shear test revealed that Controlled Dynamic Radiant (CDR) heated French fries were significantly firmer than immersion fried and oven baked French fries [7]. When dimensions of the potato strips, used during texture analysis, were taken into account (Table 1), the interpretations of the firmness results did not change. Rommens et al. [9] reported that outer potato strips, taken from outer part of the potato, had less moisture content than inner potato strips, taken from inner part of the potato. Effect of this variation was balanced by using five potato strips in each experiment. It has been reported that Kramer shear test of restructured sweet potato strips was more precise than three-point bending test and puncture test of the same samples [10]. They used eight strips in Kramer shear test, whereas only one strip was used in the other two tests with higher number of replications.

Puncture test also showed similar results with firmness test, except the force required to rupture CO baked potato strips. Even though CO baked samples had significantly (p<0.05) higher puncture force than that of RWO baked samples, there was no significant difference between puncture force of CO baked and deep-fat fried samples. When puncture force was divided by the thickness of the potato strips, used in puncture test, CO baked samples had significantly (p<0.01) higher puncture force than RWO baked and deep-fat fried samples. Lloyd et al [7] reported no significant difference in maximum peak force of the CDR heated, immersion fried and oven baked French fries, when these samples were punctured with 1mm probe.

Even though RWO baked potato strips had significantly (p<0.0001) higher moisture content than deep fat-fried samples, firmness and puncture force of the two samples were not significantly different. On the other hand, CO baked and deep-fat fried potato strips had similar moisture content, the former samples was significantly (p<0.01)
firmer than the latter. These results are in agreement with those of van Loon et al. [11] and Sanz et al [12]. It has been reported that different pre-drying and par-frying conditions alter the crispiness of the French fries, despite the fact that the final moisture content of the samples were not significantly different between samples [11]. Sanz et al. [12] also concluded that crispiness cannot be assessed by solely considering moisture content of the samples.

Table 1: Texture and color of the RWO and CO baked, and, deep-fat fried potato strips

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Firmness Force (N)</th>
<th>Firmness Force/area (N/cm²)</th>
<th>Puncture Force (N)</th>
<th>Puncture Force/thickness (N/cm)</th>
<th>Color Lightness</th>
<th>Color Chroma</th>
<th>Color Hue (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWO</td>
<td>19.48 ± 3.26b</td>
<td>4.15 ± 0.62b</td>
<td>1.26 ± 0.26b</td>
<td>1.34 ± 0.30b</td>
<td>67.55 ± 3.11a</td>
<td>35.63 ± 1.61b</td>
<td>83.86 ± 2.76a</td>
</tr>
<tr>
<td>Oven</td>
<td>36.82 ± 6.21a</td>
<td>9.05 ± 1.52a</td>
<td>2.34 ± 2.59a</td>
<td>2.76 ± 2.85a</td>
<td>64.60 ± 4.22b</td>
<td>38.76 ± 2.61a</td>
<td>79.36 ± 5.51b</td>
</tr>
<tr>
<td>Fryer</td>
<td>22.43 ± 2.70b</td>
<td>4.61 ± 0.54b</td>
<td>1.30 ± 0.63ab</td>
<td>1.32 ± 0.61b</td>
<td>62.26 ± 2.16b</td>
<td>35.01 ± 1.19b</td>
<td>79.04 ± 1.53b</td>
</tr>
</tbody>
</table>

3.5. Color
Consumer acceptance is affected by color of a product. Color is quantified in CIE Lab color space. Conversion of ‘a’ (redness/greenness) and ‘b’ (yellowness/blueness) values to chroma and hue angle was accomplished, as human perception of color is more related to chroma and hue angles [13]. Lightness, chroma and hue angle of the deep-fat fried, RWO, and, CO baked potato strips are given in Table 1. RWO baked potato strips had significantly (p<0.001) higher lightness and hue angle than deep-fat fried and CO baked potato strips. Whereas, CO baked potato strips had significantly (p<0.0001) higher chroma value than deep-fat fried and RWO baked samples. These results are in agreement with those of Lloyd et al [7] for French fries heated in CDR heater. They reported that lightness of the IR heated French fries was significantly higher than immersion fried and oven baked samples. However, they indicated no significant difference between IR heated and immersion fried French fries in terms of ‘b’. They also reported ‘b’ of the oven baked French fries was significantly higher than that of IR heated and immersion fried samples. Lightness and hue angle of the RWO baked potato strips was 67.55 ± 3.11 and 83.86 ± 2.76 °, respectively. Romani et al. [14] reported 67.46 and 95.80° as lightness and hue angle of the French fries that were deep-fat fried at 180 °C for 3 min.

3.6. Consumer Acceptability
In 105-member consumer panel, RWO processed potato strips at 365 °C for 6.5 min had 65.7% acceptability. On the other hand, deep fat fried and oven baked French fries had 97.1% and 84.8% acceptability, respectively. RWO baked potato strips had lower acceptability than deep-fat fried and CO baked samples. Lloyd et al. [7] conducted consumer acceptability test on CDR heated, oven baked and immersion fried French fries with 9-point hedonic scale. They indicated no significant difference in overall acceptability of CDR heated and immersion fried French fries. However, they stated that oven baked French fries had significantly lower overall acceptance than CDR heated and immersion fried samples.

When panelists were asked the follow-up question after nutrition facts were given, more than half (58.3%) of the panelists changed their opinion about RWO baked potato strips from unacceptable to acceptable. After follow-up question, acceptability of the specially treated French Fries was 85.7%. This showed that consumers were likely to trade off their quality standards while having reduced-fat potato strips.

RWO baked potato strips had the lowest willingness to purchase value (36.5%) among three treatments. Whereas, 83.8% and 50.5% of the panelists were willing to purchase the deep-fat fried and oven baked samples, respectively. Sensory analysis indicated that RWO baked potato strips have commercial potential, but further product development is needed to increase willingness to purchase by potential consumers.
4. Conclusion
Texture and chroma of the RWO baked potato strips were not significantly different than that of deep-fat fried samples. However, there were significant differences in moisture content, lightness, hue angle values between RWO baked and deep-fat fried samples. Although the differences, RWO baked potato strips were accepted by the consumer panel. Moreover, revealing the reduced-fat content of the RWO baked samples increased the acceptability. However, acceptability of the deep-fat fried was the highest. On the other hand, only one-third of the consumer panelists were willing to purchase the RWO baked potato strips. This result indicates that some improvement in the final product by either modifying the raw material or additional processing such as pre-cooking is needed.

References