Effects of Rice Batter on Oil Uptake and Sensory Quality of Coated Fried Okra

Fred F. Shih, Karen L. Bett-Garber, Kim W. Daigle, and Daphne Ingram

ABSTRACT: Okra was coated and deep-fat fried with batters of flour sources including rice flour, a mixture of rice flour and small amounts of pregelatinized rice flour (PGRF), and, as a control, traditional wheat flour. The addition of PGRF up to 8%, enhanced batter viscosity and the coating properties of the rice batter. Oil uptake of the fried batter decreased with the addition of up to 5% PGRF. Rice flour fried batters, with and without PGRF; were found to absorb substantially lower oil, by as much as 51%, compared with the wheat batter. The fried okra coated with the rice batter containing 5% PGRF when evaluated for sensory properties on appearance and surface attributes, was found to be superior or equal to those with the wheat batter and rice batter without PGRF. Particularly, its golden brown color is considered more desirable than the lighter yellow color of the other 2 entities. Similarly, most of its 1st-bite and after-chew properties were slightly better and were in the normal range of commercially available products. Specifically, its distinctive crispiness is considered a positive attribute, whereas its slightly higher tooth packing properties, while remaining in the range of commercial products, may be noticeable to some consumers.

Keywords: rice batter, fried okra, oil uptake, sensory quality

Introduction

Rice ingredients are popular for use in foods because they are known to be nutritious, gluten free, and hypoallergenic (Helm and Burks 1996; Yokoyama 2004). They are particularly desirable for use in infant foods or in products for people with celiac disease (gluten intolerance) (Zain and Ahamad 1985; Gallagher and others 2004). They also have the unique functional property of low oil uptake during frying, which is essential for the development of low oil food products (Mohamed and others 1998; Shih and Daigle 1999).

Crispy coatings are a critical part of the acceptance of fried foods. However, they normally absorb great amounts of oil during frying, which has become a concern because excessive oil consumption is known to contribute to obesity and many other health problems (Robert 1989). Theories on oil retention in fried foods have not been fully established. Some studies suggested that, during frying, oil simply replaces moisture that is evaporated or lost (Gamble and others 1987; Rice and Gamble 1989). Among other factors, food components and their interactions appear to play an important role in determining the oil-moisture relationship during the frying of food and, in turn, the oil uptake. Essentially, mechanisms that enable the formation of oil-barrier films or increase the water-holding capacity may reduce oil uptake (Duxbury 1989; Balasubramaniam and others 1997; Lin and Mei 2000). Thus, gums, proteins, and modified starches, including methylcellulose (Pinthus and others 1993), proteins (Mohamed and others 1998), and rice flour (Mohamed and others 1998; Shih and Daigle 1999), have been used as additives in the preparation of reduced-oil food products.

Batters have been used commercially in coating a wide variety of fried foods. However, while information is readily available in the literature on coated and uncoated animal foods, such as fried chicken drumsticks and fish sticks, relatively fewer studies are reported on coated fried foods of vegetable sources (Makinson and others 1987). Particularly lacking is information on the evaluation of oil uptake and sensory quality of fried vegetables.

In this report, we coated and fried okra with batter formulations of various flour sources, including rice flour, a mixture of rice flour and pregelatinized rice flour (PGRF), and traditional wheat flour. We then investigated and evaluated the oil uptake and sensory properties of fried products.

Materials and Methods

Materials

Long grain rice flour (RL) and PGRF (Remyflo R500P) were provided by Riceland (Stuttgart, Ark., U.S.A.) and A&B Ingredients (Fairfield, N.J., U.S.A.), respectively. Wheat flour (Pillsbury All Purpose Flour, The Pillsbury Co., Minneapolis, Minn., U.S.A.), okra, and frying oil (LouAna vegetable oil, Ventura Foods, Opelousas, La., U.S.A.) were purchased from a local market. All other chemicals used were of reagent grade and safe for human consumption.

Preparation of batter slurry

A solid mixture was prepared containing common ingredients (1.0% sodium bicarbonate, 3.0% sodium chloride, and 0.72% sodium pyrophosphate) and 95.28% flour (wheat flour, rice flour, or a mixture of rice flour and various amounts of PGRF). Batter slurries of constant solid content were prepared by adding 50 g of the solid mixture to 60 g deionized water. The batter slurry was mixed for 5 min at room temperature, equilibrated for another 5 min, and then analyzed for viscosity.

Batter viscosity was determined using an RVA-3D analyzer (Foss Food Technology Co., Eden Prairie, Minn., U.S.A.). Batter slurry (28 g) was placed in the sample cup and the viscosity in centipoise or Rapid Visco Unit (RVU) was read after spinning, 1st at 960 rpm for 10 s and then at 160 rpm for the remaining time, a total of 4 min at 30 °C. Batter slurries of comparable viscosity were also prepared by...
Table 1—Sensory appearance and texture attributes

**Appearance**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color description: the actual color name describing the batter, such as from yellow to brown, and so forth</td>
<td>0 = yellow to 15 = brown</td>
</tr>
<tr>
<td>Evenness of coating: the evenness of distribution of the batter over the product</td>
<td>0 = uneven/blotchy to 15 = even</td>
</tr>
<tr>
<td>Surface consistency: the amount of irregularity, protrusions, grains, or bumps, which can be seen on the surface of the product (batter)</td>
<td>0 = smooth to 15 = rough</td>
</tr>
<tr>
<td>Surface shine: amount of light reflected from the product’s surface</td>
<td>0 = dull to 15 = shiny</td>
</tr>
<tr>
<td>Adherence of coating: the amount of adherence of the coating to the product after frying</td>
<td>0 = no adherence to 15 = much adherence</td>
</tr>
</tbody>
</table>

**Surface attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness: the amount of particles, bumps, protrusions, or craters in the surface</td>
<td>0 = JELL-O® brand gelatin to 15 = FINN CRISP® rye wafer</td>
</tr>
<tr>
<td>Surface greasiness/oiliness: the amount of oil on the surface</td>
<td>0 = unsalted saltines to 7th = hot dog (did not have a numerical reference for 15)</td>
</tr>
</tbody>
</table>

**First bite**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness: the force to compress between the molars</td>
<td>1a = cream cheese to 14.5a = LifeSavers® hard candy</td>
</tr>
<tr>
<td>Cohesiveness: the degree to which sample deforms rather than crumbles, cracks, or breaks.</td>
<td>1a = cornbread muffin to 15 = Freedent® chewing gum</td>
</tr>
<tr>
<td>Crispiness: the force and noise with which a product breaks or fractures (rather than deforms) when chewed with molar teeth (1st and 2nd chew).</td>
<td>2a = Quaker low fat granola bar to 17a = Melba toast</td>
</tr>
</tbody>
</table>

**Chew down**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesiveness of mass: the degree to which a chewed sample (at 10 to 15 chews) holds together in a mass</td>
<td>0 = shoestring licorice to 15 = raw Pillsbury® biscuit dough</td>
</tr>
</tbody>
</table>

**After swallowing (or expectorating)**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residuals: the amount of particles remaining in the mouth after swallowing</td>
<td>0 = no particles to 15 = many particles (4.5 = cooked spaghetti)</td>
</tr>
<tr>
<td>Tooth packing/tooth sticking: the degree to which product sticks on the surface of the teeth</td>
<td>0 = canned mini clams to 15.0 = Jujuubes candy</td>
</tr>
<tr>
<td>Mouthcoating (oily): the amount of greasiness/oiliness remaining on the mouth surface</td>
<td>5a = Great Value™ brand canned/baked biscuits to 9a = Pillsbury® Grands™ baked biscuits</td>
</tr>
</tbody>
</table>

Adding various amounts of deionized water to 50 g of the solid mixture to achieve a viscosity of 1440 to 1740 cP (120 to 145 RVU). The slurry was then used for okra coating and frying.

**Coating and frying of okra**

A 5.7-L Dazey deep-fryer (Dazey Co., New Century, Kans., U.S.A.) with a strainer was used for the frying experiment. The heating was controlled by a temperature controller, Therm-O-Watch L6-1000SS (Instruments for Research and Industry, Cheltenham, Pa., U.S.A.). The oil bath, filled to a depth of 4.5 cm with 1.4 L of the vegetable oil, was heated at 177 °C.

Okra pieces were dipped and coated evenly in the batter slurry before being dropped into the fryer. After frying for 7 min, the batter-coated okra was cooled on the strainer and weighed. The fried batter crust was peeled from the okra and weighed. It was then ground in liquid nitrogen, and the resulting powder was used for oil analysis.

**Oil analysis**

Oil content was analyzed using a supercritical fluid extraction system (SFX 220, ISCO, Lincoln, Neb., U.S.A.). The sample cartridge was loosely filled with 1 g of Ottawa sand (EM Science, Gibbstown, N.J., U.S.A.) at the exit end of the cartridge, followed by 1 g of diatomaceous earth and 1.5 to 3.0 g of ground batter until the cartridge was full. Carbon dioxide (65 mL) was used to extract the sample at 7500 psi and 100 °C, and the restrictors were set at 140 °C. The flow rate was 2.5 to 2.7 mL/min (Shih and others 2004). The oil content was calculated from the weight gain of the oil collected in tubes packed with 1.5 g of glass wool during the extraction.

**Sensory analysis**

Ten panelists trained in the principles and concepts of descriptive analysis (Meilgaard and others 1999) and 1 to 10 y of experience participated in the study. The panelists were screened for interest, availability, and normal abilities to determine textual intensities. During the original training process, panelists learned fundamental properties of sensory evaluation, how to describe textural properties in common food products, development of texture definitions and methods of evaluating texture, and developing intensity scales for individual sensory properties. The fried okra lexicon used was developed at the USDA’s Southern Regional Research Center (SRRC). It included 5 appearance and 10 texture attributes (Table 1). The appearance attribute scales were developed exclusively for fried okra. Panelists were given anchors for the extreme ends of the scale. The line scale was unstructured, and panelists were instructed to mark the line at the point that placed the sample in proportion to the extreme reference points. Anchored intensity line scales were used to evaluate the texture attributes (Meilgaard and others 1999).
Texture scales were universal for all foods and not specific for fried okra. Each scale was uniquely developed for each texture attribute (Meilgaard and others 1999) and anchored with 2 or more points using the intensity of the attribute in commercial products. Texture intensity references are selected from commercial products so that they represent the attribute at different intensities to help the panelists set the scale in their minds. Published attributes (Meilgaard and others 1999) were developed by trained panels from 2 food research or technical centers. Texture attributes developed at SRRC were developed by our panelists under the guidance of a qualified panel leader. They take food items with the texture attribute and give scores to the attribute. The group of panelists come to consensus on the score for each anchor (texture product). If attribute intensity exceeds 15, the scale can be expanded; however, none of our samples approached 15, so we left the line scale end-point at 15 with most samples having the highest anchor at an intensity at or below 15. Scores were recorded on a computerized ballot system (Compusense FIVE, Compusense Inc., Guelph, Ontario, Canada). The study consisted of 2 sessions in which fried okra samples were presented, immediately after cooking, draining, and portioning onto Styrofoam plates, at 15-min intervals and analyzed under cool white fluorescent lights. A standard and 3 experimental samples were evaluated during a taste session. Each experimental sample was presented twice during the study. Each panelist’s samples consisted of 5 pieces of fried okra within a given formulation for evaluation of texture. The “standard,” which was a commercially available fried okra product, was presented and scored at the beginning of each session and served as a means of calibration for the panelists. In addition, this data served as a point of discussion for relating the experimental products to a commercial-ly available product. Panelists were divided into 2 groups for sensory evaluation. For practical purposes, the addition of PGRF is required to develop the needed viscosity and enhance the coating properties for the rice batter. However, to offset the effect of viscosity on oil uptake, it is necessary to adjust the water content. The results are also shown in Table 2. As the batter viscosity is now comparable, oil uptake of the fried batters depends solely on the batter composition. Noticeably, the oil uptake of the fried rice-batters remains substantially lower than that of the wheat batter, indicating the unique ability of rice ingredients in absorbing less oil during frying. However, the oil uptake of rice batters as a group remains practically unchanged, with or without the addition of PGRF. Apparently, the addition of PGRF in small amounts (<8%) was less of a factor on oil uptake when the viscosity was adjusted to a comparable level, than the 92% plus rice flour, which dominated the frying properties of the batter.

### Results and Discussion

#### Effect of batter viscosity

When rice batter slurries were prepared containing a constant total solid content, batter viscosity changed, depending on the batter composition. For comparison, the traditional wheat flour batter was also prepared. As shown in Table 2, the batter of rice flour alone had the lowest viscosity of 561 cP (46.8 RVU). It increased with increased PGRF in the rice batter. At 8% PGRF, the viscosity was 2340 cP (195 RVU), surpassing that of the traditional wheat batter. Oil uptake decreased with increased viscosity, and it reached a low of 22% oil at the viscosity corresponding to the 5% PGRF, before rising with further increases in PGRF and viscosity. Nevertheless, the oil uptake of rice batters was invariably substantially lower than that of the wheat batter.

Batter viscosity not only affected the oil uptake of the fried batter, but also the effectiveness of the food-coating operation. Batter viscosities lower than 1200 cP (100 RVU) are too thin to coat okra effectively, resulting in a poorly formed batter crust with a relatively high percentage oil uptake. On the other hand, batters with viscosities higher than 2400 cP (200 RVU) viscosities are too thick to coat the okra evenly, resulting in a lumpy and overly puffy fried batter crust. Also, the thick and uneven coatings are often undercooked and result in inconsistent or unusually low percentage oil-uptake values.

#### Effect of PGRF

For practical purposes, the addition of PGRF is required to develop the needed viscosity and enhance the coating properties for the rice batter. However, to offset the effect of viscosity on oil uptake, a comparable batter viscosity in the range of 1440 to 1740 cP (120 to 145 RVU) was established for all the batters by adjusting the water content. The results are also shown in Table 2. As the batter viscosity is now comparable, oil uptake of the fried batters depends solely on the batter composition. Noticeably, the oil uptake of the fried rice-batters remains substantially lower than that of the wheat batter, indicating the unique ability of rice ingredients in absorbing less oil during frying. However, the oil uptake of rice batters as a group remains practically unchanged, with or without the addition of PGRF. Apparently, the addition of PGRF in small amounts (<8%) was less of a factor on oil uptake when the viscosity was adjusted to a comparable level, than the 92% plus rice flour, which dominated the frying properties of the batter.

### Sensory evaluation

For sensory evaluation, fried okra samples were prepared by using 3 different batter formulations, based on the main flour component used, including wheat flour, rice flour, and mixed rice flour.
(a mixture of rice flour with 5% PGRF). Evaluations were conducted according to the attributes as shown in Table 1, and results of the evaluation are shown in Figure 1.

**Appearance**

The 3 formulations did not differ significantly in evenness of coating, surface consistency, surface shine, or adherence of coating. Of the 5 visual properties, including color description, evenness of coating, surface consistency, surface shine, and adherence of coating, only color description resulted in a statistically significant difference. The color of the mixed rice flour formulation resulted in a desirable golden brown product (intensity score of 7.1). Meanwhile, the wheat flour (3.1) and the rice flour (3.0) formulations gave a lighter and more yellow product. The mixed rice sample with its golden brown color looked more like the golden brown of the commercial sample used for calibration at the beginning of the panel than the wheat-based batter did, which indicates that it was in the commercially acceptable range.

**Mouth-Feel**

Of the 2 surface texture properties, roughness and surface greasiness, only roughness had any significant difference. The 2 rice formulations appeared to be slightly rougher than the wheat formulation. Commercial products can have cornmeal added, which makes them quite rough. Therefore, the greater roughness of the rice flour and mixed rice flour treatment may not be an issue with consumer acceptance.

Hardness, cohesiveness, and crispiness were 1st-bite properties and resulted in mean differences that were statistically significant. The rice flour formulations were harder than the wheat flour formulation, but the rice flour formulation was not out of the normal range of the commercially available product (mean of commercial product is 5.4 ± SE of 0.52). The cohesiveness in mixed rice flour formulation was significantly less than in the wheat flour formulation. Meanwhile, the rice flour formulation was not statistically different from the others. The mixed rice flour and the rice flour formulations were significantly crispier than the wheat flour formulation, which is likely a positive attribute. Of the after-swallowing texture attributes, mouth coating did not change between the 3 formulations. The residual particles were higher in the mixed rice flour formulation than the wheat flour. The rice flour was not different from the other 2 formulations. The tooth packing/tooth stick was significantly higher in the mixed rice flour formulation than the other 2 formulations. Tooth packing/tooth sticking is the only attribute that may need some adjustment. It is not known how far from commercially available products that this attribute can go and still be acceptable to consumers.

**Conclusions**

Low oil-uptake batters for the coating of okra have been formulated using rice flour and small amounts of the modified rice flour PGRF. The addition of PGRF provided the needed viscosity to the batter slurry for coating, and, at 5%, effectively lowered the oil uptake of the fried batter by up to 51% compared with that of the wheat batter. Based on the sensory evaluation, the same batter has some superior properties, such as crispiness or cohesiveness, which are quite desirable. It has good browning properties. Its tooth packing/tooth stick properties are a little high, but probably not out of the range of consumer acceptability.

**Acknowledgments**

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**References**


