Preparation and Characterization of Low Oil Uptake Rice Cake Donuts

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ABSTRACT

Cake donuts were prepared using wheat flour (WF), long grain rice flour (LGRF), and waxy rice flour (WRF). They were also prepared with the flours partially replaced by pregelatinized rice flour (PGRF) or propylene glycol alginate (PGA). The dough consistency was maintained at a comparable predetermined level by adjusting the water content. Without PGRF or PGA in the formulation, the WRF donut had the lowest oil uptake (11.8%) and the WF donut the highest (23.6%). With modified flour formulations, the oil uptake decreased for LGRF donuts and WF donuts. Oil uptake of the LGRF donut decreased with increased PGRF. Up to 30% PGRF could be used, with characteristics comparable to the traditional WF donuts but as much as 54% lower in oil uptake on a dry basis.

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Rice products have been in demand in recent years because rice ingredients are recognized to be nutritious, hypoallergenic, and healthy for human consumption (Anonymous 1998). Efforts are being made to develop rice-based products that are traditionally prepared from ingredients other than rice. The conversion to rice could be difficult because rice and its components have unique functional properties, which may or may not be suitable for these purposes. For example, baked goods and fried foods are normally wheat-based products, and their production relies on the leavening effect associated with the gluten component in wheat. Lacking gluten, rice may not function properly when replacing wheat in these products.

The fried food industry is huge in the United States. The donut market alone is a 3–4 billion dollar business. However, with their popularity, fried foods have also been causing concern because of health problems from the consumption of excessive fat that is involved in the products (Robert 1989). Consequently, low fat fried foods are in demand and new ones are being developed to meet the needs of the consumers. Rice ingredients have superior oil resisting properties during frying, and rice-based low fat fried foods have been developed, such as rice fries (Kadan et al 1997) and rice batters (Shih and Daigle 1999).

The theories on the oil retention in fried foods in general and donuts in particular have not been fully established. Some studies suggested that, during frying, oil simply replaces moisture that is evaporated or lost (Rice and Gamble 1989; Gamble et al 1987). 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. Essentially, mechanisms that increase the viscosity of the food system, enable the formation of oil-barrier films, or enhance the water-holding capacity may reduce oil uptake. Thus, gums and modified starches such as methylcellulose, polyvinylpyrrolidone, and pregelatinized rice flour have been used as additives in the preparation of reduced fat donuts (Henderson 1988; Prosise 1990; Pinthus et al 1992, 1993; Haywood and Myers 2001; Shih et al 2001). Methylcellulose was reported significantly more effective than powdered cellulose in reducing the amount of oil uptake in donuts and falafel balls (Pinthus et al 1992). Effects of protein additives on donut oil uptake have also been investigated (Martin and Davis 1986; Mohamed et al 1995). According to Mohamed et al (1995), donuts made with protein additives other than gluten had reduced oil absorption.

In an earlier study, low fat donuts were developed in our laboratory using mixtures of wheat and rice flours as the main ingredients (Shih et al 2001). Mixtures containing pregelatinized rice flour and acetylated rice starch effectively lower the oil uptake of donuts. In this follow-up study, donuts with rice-based only ingredients were developed and the effect of thickeners on their oil uptake and textural properties were investigated.

MATERIALS AND METHODS

Materials

Long grain rice flour (RL-100) was obtained from Rivland (Houston, TX). Waxy rice flour (Remyflo S200) and pregelatinized long-grain rice flour (Remyflo R 500 P) were from A&B Ingredients (Fairfield, NJ). Wheat flour (Pillsbury All Purpose Flour) was purchased from a local market. Propylene glycol alginate (Kelcoloid O) was provided by Kelco Co. (San Diego, CA).

Donut Preparation

Cake donut samples were prepared by mixing ingredients according to McComber and Miller (1976). The recipe for wheat donuts included 115 g of wheat flour (WF) (12.5% moisture base, mb), 24 g of egg, 50 g of granulated sugar, 5.88 g of margarine, 3.90 g of nonfat dry milk (Carnation, Nestle USA, Solon, OH), 3.60 g of baking powder (Calumet double acting baking powder, Kraft Foods, Rye Brook, NY), 0.60 g of salt, and 41.86 g of water. Eggs were beaten at high speed setting for 1 min in a standard mixer (Kitchen Aid, Greenville, OH), and then sugar was added and beaten at high speed for 1 min. The shortening and nonfat dry milk mixed with water were added, and mixed at low #1 setting for 20 sec each. The remaining dry ingredients were mixed with the dough for 45 sec on low. The dough was transferred to a cutting board and lightly dusted with the flour mix from which the dough was made. It was rolled to a thickness of ≈1.0 cm and cut to ≈4.5 × 4.5 cm squares.

Wheat flour (WF) in the formulation was replaced with long grain (LGRF) (12% mb) or waxy rice flour (WRF) (12% mb) to study its oil uptake properties. LGRF in the donut was also partially replaced with 10–30% pregelatinized rice flour (PGRF) (8.4% mb), WF or WRF were replaced with 10% PGRF, and LGRF, WF, or WRF was studied with the addition of 1% propylene glycol alginate (PGA). The resulting samples were used for dough consistency analysis and frying experiments.

Texture Measurements

The procedure for dough consistency test is a modification of the method of Collins and Aziz (1982). A texture analyzer (Stevens QTS-25, Michael G. Brown & Assoc., Newton, PA) equipped with a 25-kg load cell and 0.5-in. diameter cylindrical acrylic probe was used for the dough consistency analysis. The probe was operated at a speed of 100 mm/min and allowed to penetrate 4 mm into the dough. The peak force in Newtons (N) was recorded as dough consistency; five measurements were conducted for each sample.

Dough consistency decreased with increased water content of the dough. To maintain a consistent dry weight for the square-shaped

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dough, the sample dough was prepared by 1) keeping the height of the dough square at 9.5 mm; 2) using the dough made from wheat flour as a reference with a measurement of the square at $(45\ mm)^2$; and 3) adjusting the dimension of the sample dough square by multiplying the reference dimension $(45\ mm)^2$ with a factor obtained by dividing the total weight of the sample dough by the total weight of the dough made from wheat flour as formulated above.

Donut firmness was analyzed using the texture analyzer with a moving metal plate (7 × 10 cm). The plate compressed the sample to 20% of its length at a speed of 100 mm/min in a two-cycle test. The peak force in N displayed was recorded as the donut firmness; the measurement was conducted in triplicate. The fried donut, frozen in liquid nitrogen, was ground in a food processor, and the ground sample was used for moisture and oil analysis. Moisture content was measured in triplicate using an infrared dryer moisture analyzer (LP 16, Mettler Co., Hightstown, NJ) by spreading ≈5 g of the ground sample on the sample pan at 105°C until the weight (in mg) was constant for 2 min. Oil content was measured in triplicate using an supercritical fluid extraction system (SFX 220, ISCO, Lincoln, NB).

Frying Procedures

A 6-qt deep-fryer with a strainer (Dazey Co., New Century, KS) was used for the frying experiment. The heating was controlled using a temperature probe (Therm-O-Watch L6-1000SS, Instruments for Research and Industry, Cheltenham, PA). The oil bath, filled to a depth of 4.5 cm with 1.4L of Wesson vegetable oil, was heated at 190°C for 2 hr before use. The donuts were fried, with flipping from side to side about every 30 sec until they were golden brown on the outside and the core temperature of the fried donut reached 99–101°C. To achieve the frying properties as described, donuts with a wide range of water content in the dough were fried for different lengths of time: WF or LGRF, 2:30 min; WF + 1% PGA, 3:00 min; 90% WF + 10% PGRF, 3:15 min; LGRF + 1% PGA, 3:20 min; WRF or 90% LGRF + 10% PGRF, 3:30 min; 80% LGRF + 20% PGRF, 4:00 min; WRF + 1% PGA, 5:00 min; 70% LGRF + 30% PGRF, 5:45 min; and 90% WRF + 10% PGRF, 6:00 min. The fried donuts were drained on the strainer for 0.5 hr before being tested for firmness, moisture, and other frying properties.

Oil-Uptake Calculation

Percent of oil uptake was obtained by subtracting the initial percent oil content of the mixture of the ingredients from the final percent oil content of the fried donut. The moisture content was subtracted from the total weight of the sample, resulting in oil content on dry weight basis (dwb). The calculation was:

$$\%\ \text{Oil uptake} = [O_f / (W_f - M_f) - O_i / (W_i - M_i)] \times 100$$

where O_f, W_f, and M_f were the total oil content, total weight, and moisture weight, respectively, of the fried donut, and O_i, W_i, and M_i were the total oil content, total weight, and moisture weight, respectively, of the mixture of the ingredients. Data were obtained from three individual products, which were then used to calculate the average and standard deviation as presented in Table I. Similarly, the same procedure was used to obtain oil uptake values from individual samples using the equation above.

RESULTS AND DISCUSSION

Dough Consistency

Dough consistency is important for donut processing. For normal handling of the dough, consistencies at >0.98 N would be too hard, whereas consistencies at <0.39 N would be too soft. Invariably, dough consistency decreased with increased water content. Figure 1 shows the effect of water on the dough consistency of various donut formulations. Depending primarily on the interaction with the dough components, different amounts of water were required to achieve comparable dough consistencies. Compared with wheat dough, long grain rice dough required less water and waxy rice dough required more water to be comparable in consistencies. The correlation profile of the long grain rice dough is relatively flat (low slope) as compared with that of the wheat dough, indicating that the dough consistency of the rice flour is less sensitive to the water added. On the other hand, additions of pregelatinized rice flour or propylene glycol alginate tend to increase the water requirement to maintain comparable dough consistency for the rice dough.

Dough consistency also plays a role in determining the oil absorption properties of the donut during frying. A standard range of dough consistencies was established not only for easy processing, but also for reliable comparison of donut ingredients on characteristics such as oil-uptake properties. The dough consistency of wheat donuts provides a convenient reference. It decreased from 1.00 N at 15.8 g of water/100 g of solid, to 0.29 N at 27.1 g of water/100 g of solid (r^2 = 0.998). Traditional wheat donuts, based on the formulation of McComber and Miller (1976), contain 20.6 g of water/100 g of total solid and have a consistency of 0.59–0.62 N. In the experiments, it was established that cake donuts would be prepared by adjusting the water content to achieve dough consistencies of 0.40–0.60 N.

Effects of Thickeners

Initially, the oil content was determined for rice cake donuts containing wheat flour, waxy rice flour, or long grain rice flour. Also included were donuts with pregelatinized rice flour (PGRF) or propylene glycol alginate (PGA) included in the formulation. The results, as shown in Fig. 2, indicate that, as compared with wheat donuts, rice donuts appeared to absorb less oil (lower oil content) during frying, slightly for donuts with long grain rice flour and substantially for those with waxy rice flour. Except for the LGRF donut with no additive, rice donuts also showed an increase in moisture content, more so for those with lower oil contents. As expected, similar trends of lower oil absorption for rice donuts with and without additives in terms of oil uptake are shown in Fig. 3. Differences in the protein and starch components of the flours appear to play a role in determining the oil properties of the fried donut. For instance, the presence of the lipophilic gluten in wheat flour is not only responsible for the superior puffing and expansion

TABLE I
Oil Absorption Properties of Cake Donuts at Various Ratios of Long Grain Rice Flour and Pregelatinized Rice Flour

Composition (%)[a]			Donuts[c]			
LGRF	PGRF	Dough Consistency (N)[b]	Moisture (%)	Oil Content (% db)	Oil Uptake (% db)	Firmness (N)
100	0	0.48 ± 0.02	17.37 ± 0.35	22.88 ± 0.27	18.61 ± 0.27	9.02 ± 0.28
90	10	0.40 ± 0.03	26.50 ± 0.96	17.96 ± 0.22	13.69 ± 0.22	8.91 ± 1.23
80	20	0.42 ± 0.04	34.73 ± 0.23	16.13 ± 0.84	11.86 ± 0.84	4.11 ± 0.47
70	30	0.45 ± 0.01	38.29 ± 0.33	15.07 ± 0.19	10.80 ± 0.19	4.55 ± 0.51
Reference (100%WF)		0.41 ± 0.04	20.43 ± 0.25	27.84 ± 0.78	23.57 ± 0.78	11.97 ± 0.46

[a] LGRF, long grain rice flour; PGRF, pregelatinized rice flour; WF, wheat flour.
[b] Average of five values ± standard deviation.
[c] Average of three values ± standard deviation.

capacity of wheat dough but also a factor in absorbing more oil during frying. On the other hand, the lack of amylose in waxy rice may contribute to its lower oil uptake than the amylose-containing long grain rice because amylose tends to complex and is more compatible with oil.

Dough formulations that have strong water-holding capacity are more effective in resisting the penetration of oil during frying (Shih et al 2001). The application of thickeners, such as pregelatinized rice flour and propylene glycol alginate, enhanced the water-holding capacity of the dough and reduced the oil uptake of the fried donut. The effect was particularly pronounced with the dough of the wheat flour and the one of the long grain rice flour. The thickeners also provided the needed viscosity and adhesiveness to rice dough, such as the one from long grain rice flour, to develop the gluten-like frying characteristics. However, not all thickeners are equally effective for our purposes. Propylene glycol alginate is an extremely effective thickener, but it makes sticky dough at 1% incorporation, which limits its application as an effective additive. Pregelatinized rice flour is cheap, safe for food use, and, being a rice ingredient, an ideal component for an all-rice donut formulation.

Oil Absorption Properties of Rice Cake Donuts

To evaluate more fully the oil-lowering effect of pregelatinized rice flour (PGRF) on long grain rice flour (LGRF) donuts, donut samples were prepared using various ratios of PGRF and LGRF. For practical purposes, PGRF was used at <30% because, at >30% PGRF, the dough was too moist to cook effectively under the frying conditions as stated. Dough and fried donut properties were analyzed and the results are summarized in Table I. As discussed earlier, the dough consistency was adjusted to a given range by controlling the water content. As expected, oil uptake of the fried donut decreased with increased PGRF. Compared with traditional wheat cake donuts with ≈23.6% oil uptake, the rice cake donuts with 10–30% PGRF had oil uptake values lowered by 42–54%. For comparison, the substitution of wheat flour in donuts with 2% powdered cellulose or 1% methycellulose resulted in the reduction of oil uptake during frying by 22.54 and 26.69%, respectively (Pinthus et al 1993). The firmness values of the rice cake donuts was 4.11–9.02 N, whereas that of the wheat donut was ≈11.96 N. Generally, donuts with firmness <2.94 N are too soft, and those with firmness >12.75 N are too hard; donuts with firmness in the range of 2.94–12.75 N are considered acceptable. Therefore, up to 30% PGRF can be incorporated in the donut formulation to achieve a range of favorable characteristics. Ideally, relatively smaller amounts of modified rice flours should be used to achieve the most improvements possible. For that purpose, the donut with 10% PGRF appeared to be a good choice because, in addition to the relatively low level of PGRF, the resulting donut was most favorably comparable in terms of firmness and texture to the traditional wheat cake donut. However, the donut with 20% PGRF could also be desirable because, in addition to having a superior low oil uptake at 11.9%, it had a pleasantly soft and chewy texture comparable to a beignet (a square-shaped donut, also called French donut locally in New Orleans).

Moisture content of the fried donut increased with increased PGRF, which, in turn, was correlated negatively with the oil uptake, as measured on a dry basis. It is believed that, during frying, oil simply replaces the moisture that escapes. The amount of oil uptake has been shown to be directly proportional to the amount of moisture lost during the frying of potato slices (Rice and Gamble 1989). In the present case of the LGRF donuts, the presence of PGRF enhanced the water-holding capacity, hindered the evaporation and removal of water, and consequently reduced the oil uptake.

CONCLUSIONS

Low oil uptake rice donuts can be prepared using WRF or LGRF as the main component. Compared with the traditional WF donuts, those made with WRF, with or without PGRF, contained ≈49–60% lower oil uptake. Those made with LGRF and up to 30% PGRF had reduced oil uptake by up to 54%.

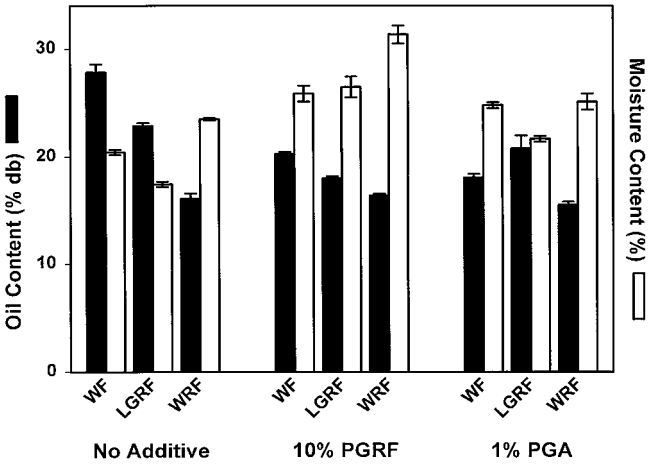

Fig. 2. Effect of additives on oil content and moisture content of cake donuts from wheat flour (WF), long grain rice flour (LGRF), waxy rice flour (WRF), 90% flour + 10% pregelatinized rice flour (PGRF), and flour with 1% propylene glycol alginate (PGA)

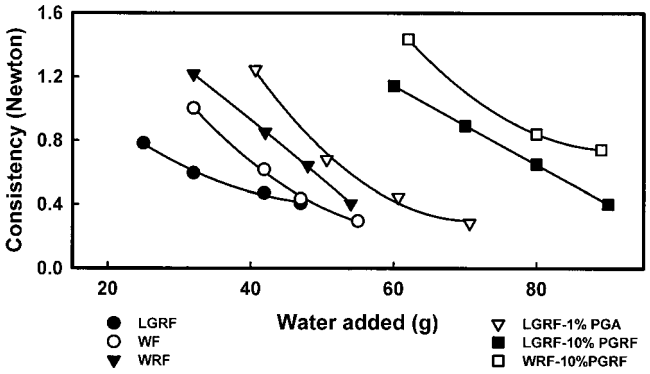

Fig. 1. Effect of water on dough consistency from long grain rice flour (LGRF), wheat flour (WF), waxy rice flour (WRF), LGRF + 1% propylene glycol alginate (PGA), LGRF + 10% pregelatinized rice flour (PGRF), and WRF + 10% PGRF.

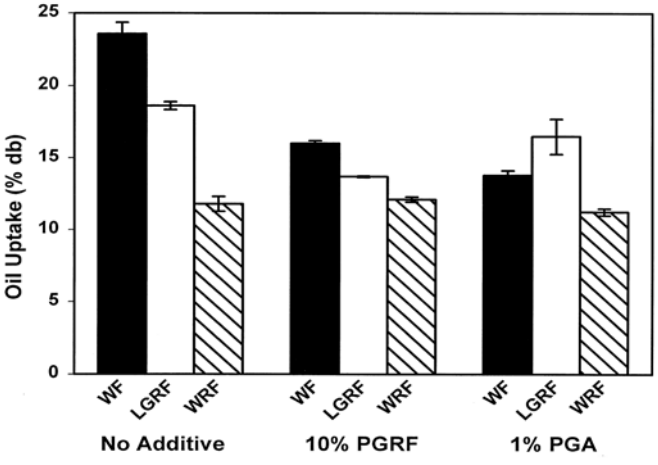

Fig. 3. Effect of additives on the oil uptake of cake donuts from wheat flour (WF), long grain rice flour (LGRF), waxy rice flour (WRF), 90% flour + 10% pregelatinized rice flour (PGRF), and flour with 1% propylene glycol alginate (PGA).

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