PHYSICOCHEMICAL PROPERTIES OF GLUTEN-FREE PANCAKES FROM RICE AND SWEET POTATO FLOURS

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ABSTRACT

Gluten-free pancakes were prepared using rice flour and rice flour replaced with various amounts, at 10, 20 and 40%, of sweet potato flour. Textural properties of the cooked pancakes, such as hardness and chewiness generally increased with time after cooking, whereas they decreased with increased sweet potato flour replacement. On the other hand, cohesiveness decreased with time, but increased with increased sweet potato flour in the pancake. Nutritional properties of the rice–sweet potato pancakes, such as protein content, dietary fiber, total carbohydrate and calories were generally comparable with those of their wheat counterpart. The only significant difference was in the beta-carotene content, which increased from 5.2 to 236.1 μ*g/g when sweet potato flour was incorporated, from 0 to 40%, into the rice pancake formulation.*

INTRODUCTION

The prevalence of celiac disease (CD), an intolerance of gluten, has been reported to be as high as one in 200 of the world population (Fasano and Catassi 2001). The majority of those diagnosed with this disease are "silent" and latent cases, which have the potential but may or may not develop the disease (Feighery 1999). Nevertheless, CD is a serious health issue and a

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challenge for food scientists, because it can only be treated by strict adherence to a gluten-free diet. Developing gluten-free foods, regulated to have a gluten level not exceeding 200 ppm, is difficult because gluten is very common in food sources. Also, attempts to remove the gluten ingredient in foods may result in the loss of nutritional balance of the products (Mariani *et al*. 1998; Grehn *et al*. 2001).

Rice is naturally gluten-free and contains proteins that are known to be nutritious and hypoallergenic (Helm and Burks 1996). Rice flour has been used to prepare gluten-free bakery products, such as breads and cakes, which are traditionally made with wheat flour (Cato *et al*. 2004). Pancakes are another popular wheat-based product that can be reformulated to be nonwheat and gluten-free. Conventional wheat pancakes have been studied extensively on processing conditions for the improvement of texture and flavor (Seguchi 1990, 1993; Seguchi *et al*. 1998). Essentially, the studies found that treatments of wheat flour (starch), such as chlorination and heating, increased its hydrophobicity and, as a result, pancakes prepared with the modified flour showed improvements in springiness. Also reported is the study on flavor formation during frying and subsequent flavor losses during storage and microwave reheating in wheat pancakes (Li *et al*. 1994). Rice flour has the potential to be a wheat flour substitute in pancakes. However, little information is available on the use of rice flour for gluten-free products such as pancakes.

Sweet potato is an economical and healthful food crop that has been widely grown in the southeastern U.S.A. It is also gluten-free and particularly rich in beta-carotene (pro-vitamin A), potassium, dietary fiber and many other healthy ingredients (Woolfe 1992). Sweet potato can be processed into flour, flakes, purees, canned products, beverages and various snack foods. Sweet potato flour and flakes can partly substitute for wheat and other cereals flours, and enrich beta-carotene content in bakery products and pancakes (Woolfe 1992). As with rice flour, there is scant information in the literature on the effect of substituting wheat flour with rice and sweet potato flours on the physical and chemical properties of the traditional wheat pancakes.

In this study, our objective was to develop gluten-free pancakes to meet the need of people with celiac disease. We prepared pancakes using different ratios of rice and sweet potato flours. Rheological, nutritional and textural properties of these rice–sweet potato pancakes are also presented.

MATERIALS AND METHODS

Long grain rice flour was obtained from Riceland Foods (Stuttgart, AR). Wheat flour (Pillsbury's Best All-Purpose Flour, Minneapolis, MN), Beauregard sweet potatoes (grown in Louisiana) and other food ingredients, including

Egg Beaters (Egg Beaters, ConAgra Foods, Downers Grove, IL), nonfat milk powder (Carnation, Nestle U.S.A., Solon, OH) and baking powder (Calumet double-acting baking powder, Kraft Foods, Rye Brook, NY) were purchased from local supermarkets in New Orleans, LA. All other chemicals used were of reagent grade, and are suitable for food uses.

Sweet potatoes were washed, peeled and sliced in a food processor (Kitchen Aid, Greenville, OH). The sweet potato slices were soaked in 0.1% sodium metabisulfite for 5 min to reduce browning, strained, frozen in liquid nitrogen and freeze-dried (Hall 2000). The dried slices were ground to a powder in the food processor and stored at −20C.

Pancake Preparation

Rice flour and sweet potato flour substituted for wheat flour in traditional pancakes on an equal weight basis. Of the total flour in the mixture, rice flour was replaced with 0, 10, 20 and 40% of sweet potato flour. Wheat flour-based pancakes were used as a control. To a mixture of dry ingredients, including flour (97.7 g), salt (2.0 g), sugar (19.7 g), baking powder (4.2 g) and nonfat dried milk (15.0 g), were added water (108.4 g) and Egg Beaters (39.1 g) to make a batter slurry. The slurry was mixed with a spatula for 45 s. Ninety milliliters of the batter was poured on the preheated griddle of a commercial pancake maker (Pancake Factory, Select Brands, Inc., Lenexa, KS) that had been lightly sprayed with an antistick cooking spray (Pam, International Home Foods, Parsippany, NJ). The pancakes were cooked at 175C for 2.5 min until the upper surface bubbled. The pancake maker was then closed, and turned to cook the other side, which browned in another 2–3 min. Pancake samples using various ratios of rice and sweet potato as well as the wheat counterpart were similarly prepared to be used as samples in the precooked pancake experiments. In this case, the cooked pancakes were cooled to room temperature, wrapped in plastic bags and stored at −20C for 1 week. The frozen pancake was reheated for 30 s at 50% power in a 1000-W Menumaster microwave oven (Amana, IA). It was tested in the same manner as the freshly prepared pancake.

Analyses

Constant rate measurement of batter viscosity as a function of shear rate was performed at 25C with a StressTech rheometer (Reologica Instruments AB, Lund, Sweden) using a cone and plate geometry (C40 4). Apparent viscosity was recorded as shear rates that were ramped from 0.1 to 300/s. Two repeated measurements were performed on each of the duplicated samples.

Pancake texture was tested on a Steven's QTS Texture Analyzer (Michael G. Brown & Assoc., Inc., Newtown, PA) using texture profile analysis (TPA).

The pancake texture was measured over a 25-min period immediately after cooking while the pancake cooled. A flat 1-in. (2.54-cm) acrylic cylinder was used in the double bite compression test with a 5-g trigger point. The probe compressed the sample at 100-mm/min test speed until a 50% deformation target was reached. Textural properties were calculated using Steven's Profile software. The following TPA parameters were calculated from the force–deformation curve. Hardness, defined as the peak force necessary to attain 50% deformation, is presented as a ratio of force divided by thickness (g-force/mm). Cohesiveness was calculated by the QTS software as the total positive work done in cycle 2 divided by the total positive work done in cycle 1. Springiness is defined as the sample length of the pancake in the second compression. Chewiness was calculated as hardness × cohesiveness × springiness.

The cooked pancake, frozen in liquid nitrogen, was ground in a food processor, and the ground sample was used for moisture, protein and oil analyses. Moisture content was measured in triplicate using a Mettler LP 16 infrared dryer moisture analyzer (Mettler Co., Hightstown, NJ) by spreading about 5 g of the ground sample on the sample pan at 105C until the weight (in mg) was constant for 2 min. Nitrogen content of the sample was determined by the combustion method using a LECO FP-428 nitrogen analyzer at 950C combustion temperature (LECO Corp., St. Joseph, MI). Protein content was calculated as %N × 6.25. Oil content was analyzed using a supercritical fluid extraction system (SFX 220, ISCO, Lincoln, NB). The sample cartridge was loosely filled with 1 g of sand at the exit end of the cartridge, followed by 1 g of diatomaceous earth and 2–3 g of ground sample until the cartridge was full. Carbon dioxide (65 mL) was used to extract the sample at 7500 psi and 100C. The restrictors were set at 140C and the flow rate was 2.5–2.7 mL/min. 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.

For beta-carotene analysis, 2.5 g of pancake sample was mixed with 2 g of calcium carbonate, homogenized in 25 mL methanol, and the slurry was filtered. The residue was further extracted (3×) with 50 mL of a 1:1 v/v hexanes–acetone mixture (Emenhiser *et al*. 1999). The combined filtrates were mixed with 10-mL deionized water and 2-mL saturated sodium chloride in a separatory funnel, and the aqueous–methanol–acetone layer was discarded. The hexane layer, washed with 10 mL of water (2×), was transferred to a 50-mL volumetric flask and adjusted to volume with hexane, and stored at –20C until analyzed. Beta-carotene was analyzed by reversed-phase liquid chromatography (Thermo Finnigan, Somerset, NJ) using an Alltech C18 Prevail column, a mobile phase of 42.5:42.5:15 (v/v) methanol–acetonitrile–chloroform at a flow rate of 1.2 mL/min. Column effluent was monitored at 450 nm with a UV-visible detector. Quantification of beta-carotene was performed using an all-*trans* β-carotene standard (Type I, Sigma Chemical Co., St. Louis, MO).

Ash analysis was conducted by the direct ignition method with overnight heating at 525C (Shih *et al.* 1999). Calories were calculated using 4 kcal/g for protein and carbohydrate, and 9 kcal/g for fat. Total carbohydrate was calculated as 100% − % of (protein + fat + moisture + ash). The bulk densities of pancakes were determined by displacement of rapeseeds. Total dietary fiber was analyzed with a kit from Sigma (Sigma Chemical Co.). Freeze-dried pancake samples were digested with α-amylase, protease and amyloglucosidase before precipitation with ethanol. The replicate samples were filtered and washed, and then half of the sample residues were analyzed for remaining protein content and half for ash content. Total dietary fiber was determined as the weight of the residue minus weights of protein and ash.

RESULTS AND DISCUSSION

Viscosity of Pancake Batters

Flow behavior of the pancake slurry is important in the pancake preparation. Batter viscosity affects the appearance, texture and sensory quality of the finished products. Figure 1 shows the apparent viscosity as a function of shear rate for pancake batters of rice flour, rice flour partially replaced by sweet potato flour and the traditional wheat flour. In general, at low shear rates at <50 (1/s), the apparent viscosity of all batters decreased sharply with increased shear rate. Further increase in shear rate greatly lowered the rate of decrease in apparent batter viscosity. At higher shear rates than 50 (1/s), relative differences in viscosity among batter samples remained unchanged. The viscosity curve of rice-only batter was substantially lower than that of the wheat batter. Rice flour has been reported to have lower water-holding capacity and absorb less water than wheat flour at comparable solid content (Shih *et al.* 2001). As a result, there was more free water available to facilitate the flow of particles in the rice batter, and its viscosity was lower compared to more hydrated systems like wheat batter. On the other hand, the viscosity curves were higher for the rice–sweet potato batters with increased sweet potato levels. Therefore, the addition of sweet potato is desirable because it apparently enhanced the hydration capacity of the rice batter and resulted in increased batter viscosity, which was more comparable with that of the traditional wheat batters.

Textural Analysis

As pancakes are normally consumed within 10 min after cooking, textural properties of freshly prepared pancake samples were analyzed as a

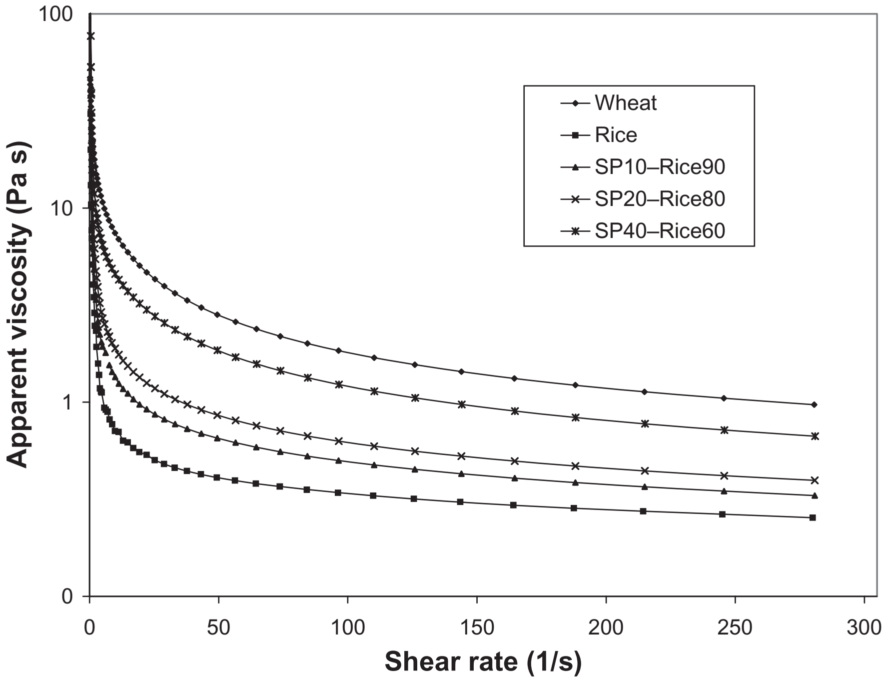

FIG. 1. APPARENT VISCOSITY AS A FUNCTION OF SHEAR RATE FOR PANCAKE BATTERS OF RICE FLOUR, RICE FLOUR PARTIALLY REPLACED WITH SWEET POTATO FLOUR AND WHEAT FLOUR
SP, sweet potato.

function of time. As expected, hardness increased with cooling time (Fig. 2a). Rice pancakes were normally harder than the traditional wheat pancake, but the rice pancake hardness decreased with increased sweet potato flour in the pancake. At 40% sweet potato flour, pancake hardness at relatively low cooling time was comparable with that of the wheat pancake control. Similar trends appeared to be true for chewiness, as shown in Fig. 2b, which decreased sharply with the addition of 10% sweet potato flour and slightly increased with time after cooking. Further increase of sweet potato flour in the formulation from 20 to 40% at relatively long cooling time resulted in pancakes with chewiness comparable with that of the wheat pancake control. However, for cohesiveness, the overall trends were opposite those of hardness and chewiness, particularly at higher levels of sweet potato flour. As shown in Fig. 2c, at sweet potato contents higher than 20%, pancake cohesiveness decreased with time after cooking and increased with increasing sweet potato flour in the rice pancake. At sweet potato lower than 20%, pancake cohesiveness was

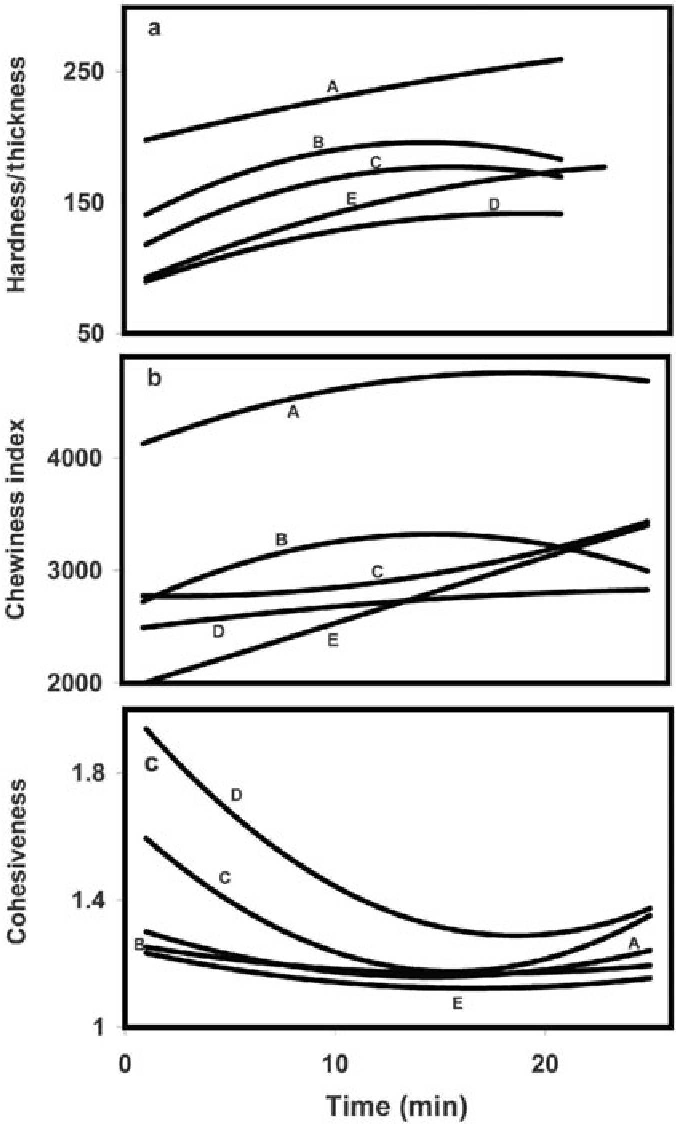

FIG. 2. TEXTURAL PROPERTIES OF FRESHLY PREPARED PANCAKE SAMPLES AS A FUNCTION OF TIME

(a) Hardness/thickness (g-force/mm); (b) cohesiveness (total positive work done cycle 2 divided by total positive work done cycle 1); and (c) chewiness (cohesiveness × hardness × springiness). Samples are designated A, B, C and D for rice pancakes with 0, 10, 20 and 40% sweet potato, respectively. Sample E is 100% wheat pancake as a control.

comparable with that of the wheat pancake control for the entire 25 min after cooking. Interestingly, springiness remained practically unchanged, retaining about 99% of the original springy form, in the 25-min time tested (not shown).

The trends of decreased hardness, decreased chewiness and increased cohesiveness hold true with increased addition of sweet potato flour up to 40%. Based on the data shown in Fig. 1, rice–sweet potato pancakes appeared to have the best combination of textural properties (most comparable with those of the traditional wheat counterpart) when sweet potato was added in the range of 20–40%. Under the conventional cooking conditions (4–6 min at 170–180C), pancakes highly enriched with sweet potato (>50%) tended to be overcooked on the surface and undercooked on the inside. The uneven cooking resulted in poor product quality.

Precooked pancakes, which are frozen and ready for consumption after microwave reheating, have become popular in recent years. Precooked counterparts of the rice–sweet potato pancakes were prepared, and their textural properties were evaluated. The overall trends on the effect of sweet potato levels on the textural properties of the product remained unchanged (Fig. 3). However, these trends were not as clear for the reheated rice pancakes as they were for the freshly prepared ones. For instance, as shown in Fig. 3a, pancake hardness decreased gradually with increased levels of sweet potato flour, but the decrease at 40% sweet potato flour replacement was relatively small, and the rice–sweet potato pancake remained noticeably harder than the wheat pancake control. Similarly, as shown in Fig. 3b, pancake chewiness decreased slightly with increased sweet potato, but at up to 40% sweet potato, the rice pancake remained more chewy than the wheat pancake control. Cohesiveness, as shown in Fig. 3c, generally increased slightly with increased levels of sweet potato. In a general trend, the overall effect of sweet potato at up to 40% replacement on the textural properties of reheated rice pancakes, as compared to that of the freshly prepared, was relatively small and insignificant.

Composition Analyses

Most cereal flours contain less than 9% protein, and most of the other major components of pancake are also relatively low in protein. The protein content for rice–sweet potato pancakes ranged from 6 to 7%, whereas it is about 9% for the conventional wheat pancake (Table 1). Oil content was minimal (less than 1%) for all pancakes, whereas dietary fiber was less than 5%. As expected, the only significant change was the increase in beta-carotene of the pancake when sweet potato flour was incorporated, because sweet potato is known to be a rich source of this nutrient. Beta-carotene in the 60:40 rice–sweet potato pancakes was 56 times greater than that of the traditional wheat pancake. Values for calories, ash, moisture and density were found to be

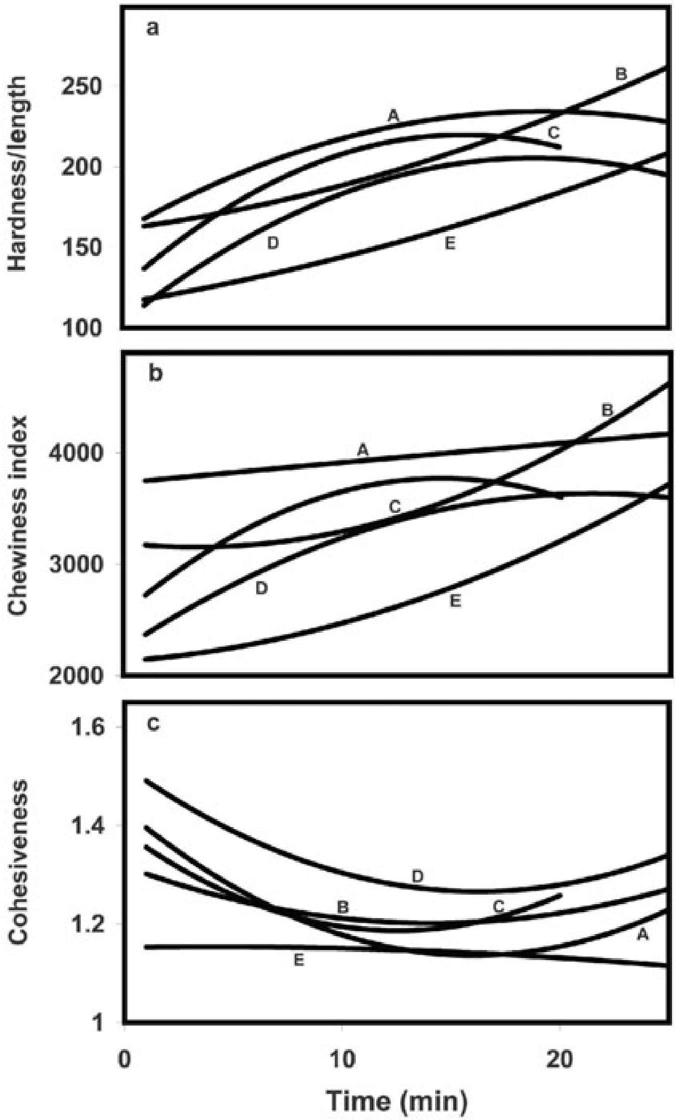

FIG. 3. TEXTURAL PROPERTIES OF PANCAKE SAMPLES, STORED FROZEN AND THEN REHEATED IN MICROWAVE OVEN, AS A FUNCTION OF TIME

(a) Hardness; (b) cohesiveness (total positive work done cycle 2 divided by total positive work done cycle 1); and (c) chewiness (cohesiveness × hardness × springiness).

Samples are designated A, B, C and D for rice pancakes with 0, 10, 20 and 40% sweet potato, respectively. Sample E is 100% wheat pancake as a control.

TABLE 1.
NUTRITIONAL CHARACTERIZATION OF PANCAKES PREPARED BY RICE FLOUR, RICE FLOUR PARTIALLY REPLACED BY SWEET POTATO AND WHEAT FLOUR*

Properties	Rice pancakes				Wheat pancakes
	0%	10%	20%	40%	
	Sweet potato				
Protein (%)†	7.04 ± 0.10	6.84 ± 0.10	6.50 ± 0.09	6.13 ± 0.06	8.79 ± 0.01
Oil (%)	0.26 ± 0.02	0.52 ± 0.02	0.35 ± 0.03	0.22 ± 0.02	0.24 ± 0.01
Carbohydrate (%)‡	40.26	42.01	42.34	42.54	36.79
Total dietary fiber (%)	2.50 ± 0.03	1.13 ± 0.03	1.37 ± 0.01	3.36 ± 0.00	4.71 ± 0.01
Beta-carotene (μg/g dry)	5.22	75.02	120.86	236.07	3.47
Calories/30-g serving§	57	60	60	59	55
Ash (%)	2.44	2.53	2.52	2.70	2.38
Moisture (%)	50.00	48.10	48.29	48.41	51.80
Density	0.78 ± 0.04	0.67 ± 0.04	0.64 ± 0.03	0.66 ± 0.05	0.77 ± 0.02

* Values reported as mean ± SD.
† Calculated by multiplying %N by the conversion factor of 6.25.
‡ Total carbohydrate was calculated as 100% – % of (protein + fat + moisture + ash).
§ Calories were calculated using 4 kcal/g for protein and carbohydrate, and 9 kcal/g for fat.

similar for all the pancakes (Table 1). Therefore, rice pancakes containing up to 40% sweet potato flour appeared to be nutritionally equal to, if not more desirable than, the traditional wheat pancakes considering the increase in beta-carotene content.

CONCLUSION

The incorporation of sweet potato flour in the formulation of rice pancakes was found to improve the physicochemical properties of the product. Rice–sweet potato pancakes, at 20–40% sweet potato flour incorporation, showed a flow behavior more like that of the traditional wheat batter and was more useful for pancake preparation. Textural properties such as hardness, chewiness and cohesiveness were improved and became comparable with those of the wheat pancake control. Protein content, dietary fiber, total carbohydrate and calories differed very little for all pancakes. However, rice–sweet potato pancakes had substantially higher contents of beta-carotene, which can enrich the dietary status in segments of the population that could be consuming low amounts of beta-carotene in their diets.

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