The Substitution of Powdered Carrot Pulp for Butter in Brownies

Pichayasinee Kachornsethakarn, Sanruthai Ariyabaraneekul, Thanaporn Kaemongkolsuk
Princess Chulabhorn Science High School Pathumthani,
51 Moo 6, Bo Ngen, Lad Lum Kaew, Phatumthani, Thailand, 12140
Email: pichayasinee13@gmail.com

Abstract

The reduction of butter in bakery products can have positive health benefits for consumers. Carrot pulp, a byproduct of making carrot juice, is available to bakeries that also sell fresh juices and smoothies. The substitution of reconstituted powdered carrot pulp for butter in a brownie recipe was investigated. It was found that substituting carrot pulp for 25% of the butter in the recipe was accepted by consumers, but more than this was rated as less appealing than the original recipe. Substitution of powdered carrot pulp for butter in brownies up to 25% is recommended, as it provides benefits including the reduction in health risk from butter consumption, reduced caloric content, and reduced costs for the bakery.

***Keywords*:** brownies, carrot pulp, butter substitute, healthy brownies, health risk

I. INTRODUCTION

The consumption of bakery products has become very common in Thailand. Most bakery products contain three basic ingredients: flour, sugar, and butter or oil. Butter contains up to 9% trans-fat and up to 50% saturated fats, both of which are known contributors to increased risk of coronary disease[1]. The consumption of butter is also known to increase the risk of a range of diseases including obesity, arteriosclerosis and diabetes[2]. In order to reduce the unhealthy effects of consuming butter, it is possible to substitute other ingredients in bakery products. Pachekrepapol et al have shown that malva nut gum can be partially substituted for butter in brownies[3], while other studies have investigated the substitution of other ingredients to increase nutritional value and reduce health risks in a variety of bakery and food products[2,4,5].

Many bakeries also offer freshly made fruit juices and smoothies for sale. When making carrot juice, there is a significant amount of carrot pulp left over after the juice has been extracted. Bakeries typically have no way to use this by-product and thus dispose of it as waste. Carrot pulp has significant nutritional value[6], so using powdered carrot pulp as a substitute for butter in bakery products would have many benefits, including decreasing the health risks from butter consumption and increasing the nutritional value of the product. The use of the carrot pulp would also significantly reduce the cost of the product for the bakery, as butter represents approximately 40% of the cost of the ingredients at typical wholesale prices in Thailand, according to the authors' estimate. Here we investigate the possibility of substituting powdered carrot pulp for butter in brownies.

Powdered carrot pulp made from the byproduct of juicing carrots, shown in figure 1, was substituted for butter in a brownie recipe at proportions ranging from no carrot pulp to 100% substitution of carrot pulp. Each of the recipes was tested for Hardness,

Figure 1. A sample of the carrot pulp remaining after juicing (left), and the dried carrot powder used in the recipe (right)

Ingredients	Recipe 1 (g)	Recipe 2 (g)	Recipe 3 (g)
Cocoa	60	80	80
Flour	75	190	190
Sugar	220	235	235
Butter	160	150	170
Eggs	100	100	100
Butter Flavor	10	10	10
Chocolate Chips	50	50	50

Figure 2. Ingredients of the tested recipes. For each recipe, ingredients were mixed in order, and baked at 150°C for 20 minutes.

Springiness, Cohesiveness, Toughness and Chewing Strength according to food industry standards, using a Texture Analyzer[7]. The color quality of the recipes was tested using a Colorflex. The Colorflex evaluates the color on three scales: 1. Lightness (L), with higher values indicating lighter overall hue, 2. Red-Green (a) with higher values indicating more red, and 3. Yellow-Blue (b) with higher values indicating more yellow[8]. The caloric content of each of the recipes was also measured using a bomb calorimeter. Finally, the recipes were evaluated by consumers for the qualities of Appearance, Color, Aroma, Taste, and Overall Appeal on the 9-point hedonic scale, which has been shown to be a reliable measure of consumer preference in the food industry[9].

II. METHODS

Brownie Recipe Selection

Three different brownie recipes (figure 2) were baked according to the recipe instructions. Each recipe was then evaluated on the 9-Point Hedonic Scale, where 9 means most liked and 1 means most disliked, for the qualities of Appearance, Color, Aroma, Taste, and Overall Appeal. The recipes were evaluated by a sample of 30 consumers, consisting of 10 adults and 20 high school students, evenly divided by gender. The recipe scoring the best overall was selected as the standard test recipe for the investigation. The selected brownies are shown in figure 3.

Figure 3. The baked brownies (right) cut up into 2 cm by 2 cm pieces for testing (left).

Powdered Carrot Pulp Preparation and Reconstitution Testing

Carrot pulp remaining from the juicing process was added to water at a ratio of 1:2 and boiled for 10 minutes. After straining to remove the water, the remaining pulp was baked at 105° for three hours. It was then ground into a powder and used in the investigation.

The powdered carrot pulp was tested to determine the appropriate ratio of water to reconstitute for use as a substitute for butter in the recipes. Ratios of carrot powder to water ranging from 1:1 up to 1:10 were tested to determine the ratios at which the powder could absorb and hold the water for 5 minutes. The powder and water mixtures were placed in filter paper in a funnel, and the mass of water that dripped out of the bottom of the funnel after 5 minutes was measured. Successful ratios were further tested for their ability to hold the water for up to 30 minutes.

Carrot Powder Substitution Recipes and Testing

Reconstituted powdered carrot pulp was substituted for butter in the selected recipe at ratios of 0%, 25%, 50%, 75% and 100% substitution and prepared according to the recipe instructions.

Each of the 5 recipes was tested for color qualities using a Colorflex for a total of 3 trials. The caloric content of each recipe was measured with a bomb calorimeter for 2 trials each. A Texture Analyzer was used to measure Hardness, Springiness, Cohesiveness, Toughness and Chewing Strength for

Recipe	Appearance	Color	Aroma	Taste	Overall Appeal
Recipe 1	7.8 ± 1.2 [a]	8.2 ± 0.9 [a]	7.8 ± 1.0 [a]	8.2 ± 0.6 [a]	8.0 ± 0.8 [a]
Recipe 2	6.8 ± 1.8 [b]	7.7 ± 1.1 [a]	7.2 ± 1.8 [b]	7.4 ± 0.8 [b]	7.5 ± 1.0 [ab]
Recipe 3	7.1 ± 1.4 [b]	7.7 ± 1.4 [a]	7.2 ± 1.3 [b]	7.2 ± 1.3 [b]	7.4 ± 1.4 [b]

Figure 4. The results of the consumer testing of the three recipes. The superscript letters following each value indicate statistically significant differences ($p < 0.05$) in each quality tested. Recipe 1 is preferred at a statistically significant level for all qualities except Color.

a total of 5 trials each. Finally, each recipe was rated by the same 30 consumers on Appearance, Color, Aroma, Taste, and Overall Appeal, using the 9-point hedonic scale. All data were analyzed for variance and difference ($p < 0.05$) using Analysis of Variance (ANOVA) and Ducan's New Multiple Range Test (DMRT) with a statistical analysis program.

III. RESULTS AND DISCUSSION

Brownie Recipe Selection

The results of the consumer ratings of the three recipes on the 9-Point Hedonic Scale are shown in figure 4. The consumer ratings for each quality is shown, with superscript letters indicating statistically significant differences ($p < 0.05$). It was found that Recipe 1 was preferred by the consumer sample at a statistically significant level in terms of Appearance, Aroma, and Taste. Recipe 1 was preferred over Recipe 3 in Overall Appeal at a statistically significant level, but showed no significant preference over Recipe 2. There was no significant difference between the three recipes in terms of Color preference. Recipe 1 was chosen as the preferred recipe for testing in the investigation.

Powdered Carrot Pulp Reconstitution

The powdered carrot pulp was thoroughly mixed with varying ratios of water and tested to determine its ability to hold the water for 5 minutes when placed in filter paper. The results (figure 5) show that ratios of carrot powder to water of up to 1:6 held the water for 5 minutes. Further testing showed that ratios up to 1:6 continued to hold the water for up to 30 minutes. Powdered carrot pulp reconstituted with water at a ratio of 1:6 was used for the test recipes.

Ratio Carrot Powder:Water	Mass of Water Released (g)
1:1	0.00
1:2	0.00
1:3	0.00
1:4	0.00
1:5	0.00
1:6	0.00
1:7	0.02
1:8	0.04
1:9	0.07
1:10	0.09

Figure 5. The results of the test of the ability of the reconstituted carrot powder to hold water for 5 minutes. Carrot powder mixed with water up to a ratio of 1:6 held all the water for up to 30 minutes.

% Carrot Pulp Substitution	Lightness (L)	Red-Green (a)	Yellow-Blue (b)
0%	20.98 [a]	1.99 [a]	1.23 [a]
25%	20.28 [b]	1.46 [b]	1.42 [a]
50%	19.88 [bc]	1.32 [b]	1.31 [a]
75%	19.60 [c]	0.38 [c]	0.55 [b]
100%	19.12 [d]	0.36 [c]	0.54 [b]

Figure 6. The Colorflex measurements for the recipes with different proportions of carrot pulp substituted for butter in the selected recipe. The superscript letters following each value indicate statistically significant differences ($p < 0.05$) in each quality tested.

% Carrot Pulp Substitution	Caloric Content (cal/g)
0%	4660
25%	4340
50%	3870
75%	3490
100%	2980

Figure 7. The caloric content of the recipes with carrot pulp substituted for butter. As expected, the caloric content decreases with increasing amounts carrot pulp.

Carrot Powder Substitution Recipes Testing

Reconstituted carrot powder was substituted for butter in the selected recipe at ratios ranging from 0% up to 100%, as described above. The results of the Colorflex tests are shown in figure 6. The 'L' values decrease, indicating the recipes become increasingly dark with increasing percentages of carrot pulp. The recipes also show a trend of becoming less red as more carrot pulp is substituted for butter, as the 'a' values decrease significantly at the higher substitution values. On the Yellow-Blue scale, carrot pulp substitution up to 50% shows no significant change in color, but the 75% and 100% carrot pulp recipes are measured as more blue.

The caloric content of each of the recipes was measured using a bomb calorimeter. The results are shown in figure 7. The caloric content of the brownies decreased by 7-10% with each 25% increase in percentage of carrot pulp substitution.
Each recipe was also tested with a Texture Analyzer for Hardness, Springiness, Cohesiveness, Toughness and Chewing Strength. The normalized values for the five qualities for each of the recipes tested is presented in figure 8, showing the relative change in

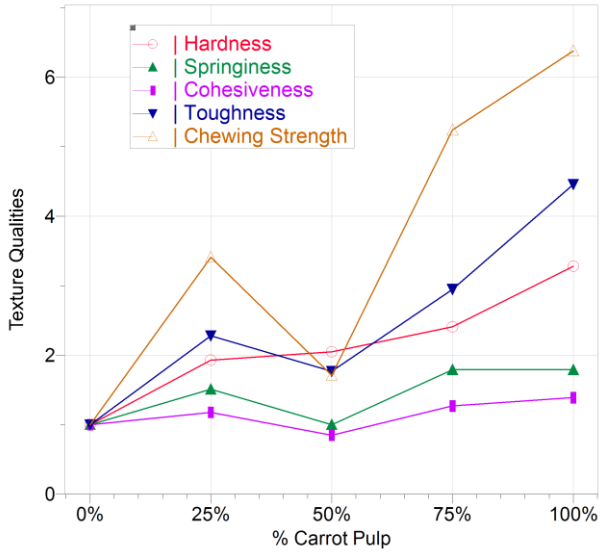

Figure 8. The average values of the texture analysis in the five qualities for each of the recipes tested.

each of the qualities measured for the five recipes tested. Increasing percentages of carrot pulp had relatively little effect on the Springiness and Cohesiveness of the brownies, but the Hardness, Toughness, and Chewing Strength increased by factors of around 3, 4, and 6 respectively.

The results of the statistical analysis of the texture analysis are shown in Figure 9. All of the recipes with substituted carrot pulp show a statistically significant increase compared to the original recipe in the qualities of Hardness, Cohesiveness, and Toughness. Interestingly, the recipe with 50% carrot pulp showed no significant difference with the original recipe in terms of Springiness and Chewing Strength, even though the 25% carrot pulp recipe showed significant increases in both these qualities, compared to the original recipe. It is not clear why this occurred. Further investigation into possible

% Carrot Pulp Substitution	Hardness	Springiness	Cohesiveness	Toughness	Chewing Strength
0%	1690 ± 30 ^{a}	0.43 ± 0.01 ^{a}	0.33 ± 0.01 ^{a}	570 ± 10 ^{a}	246 ± 3 ^{a}
25%	3260 ± 280 ^{b}	0.65 ± 0.13 ^{b}	0.39 ± 0.29 ^{b}	1300 ± 150 ^{b}	840 ± 100 ^{b}
50%	3460 ± 430 ^{b}	0.43 ± 0.28 ^{a}	0.28 ± 0.17 ^{c}	1010 ± 170 ^{b}	420 ± 65 ^{a}
75%	4070 ± 310 ^{b}	0.77 ± 0.64 ^{c}	0.42 ± 0.01 ^{d}	1680 ± 110 ^{c}	1290 ± 140 ^{c}
100%	5550 ± 300 ^{c}	0.62 ± 0.17 ^{b}	0.46 ± 0.01 ^{b}	2540 ± 130 ^{d}	1570 ± 60 ^{d}

Figure 9. The results of the Texture Analysis for the recipes with carrot pulp substituted for butter in the selected recipe. The superscript letters following each value indicate statistically significant differences ($p < 0.05$) in each quality tested.

interactions between ingredients in different proportions is suggested.

Finally, each recipe was evaluated by the original consumer sample of 30 people on the qualities of Appearance, Color, Aroma, Taste, and Overall Appeal, using the 9-Point Hedonic Scale, with 9 being the most attractive. The average values for the five qualities for each of the recipes tested is presented in figure 10. The downward trend in consumer preference is clear for all of the qualities. Appearance and Color show the least decrease with increasing pulp substitution, while Taste and Overall Appeal show the greatest. The recipe with 25% carrot pulp shows little decrease for most of the qualities compared to the original recipe, but all the other recipes show much greater reductions in customer appeal.

The results of the statistical analysis of the consumer rating data are shown in figure 11. Consumers showed no statistically significant preference for the appearance of the brownies up to a substitution rate of 50%. In terms of Color, all recipes with carrot pulp substitutions were rated as less attractive by the consumer sample. For the qualities of Aroma, Taste, and Overall Appeal, consumers showed no statistically significant difference in their preference for the 25% carrot pulp recipe compared to the original recipe, while all recipes 50% or over were rated less favorably in these areas.

Considering the Colorflex measurements in the context of the consumer preference results, it seems that increased darkness with increasing percentages of carrot pulp, along with the change in the red-green balance, was less attractive to consumers.

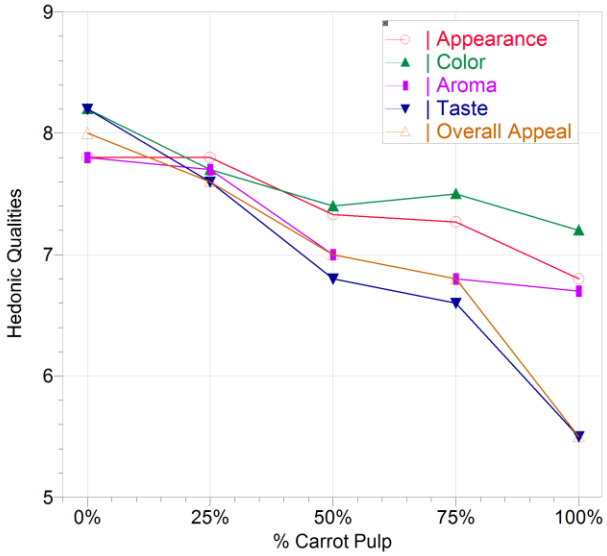

Figure 10. The average values of the consumer ratings in the five qualities for each of the recipes tested.

The correlation between the Texture Analysis and consumer response is less clear. The Hardness, Toughness and Chewing Strength of all recipes with substituted carrot pulp was measured at between 2 and 7 times greater than the original recipe. Increasing levels of carrot pulp substitution roughly corresponded to increasing values measured for each of these qualities, and also matched the general trends of the subjective qualities rated by the consumers, but at reduced differences in levels. However, the results showing the Springiness and Chewing Strength of the 50% carrot pulp recipe as statistically the same as the original recipe is not reflected in the consumer evaluations.

The results of this investigation indicate that bakeries may substitute 25% of the butter in the tested brownie recipe with reconstituted carrot pulp

% Carrot Pulp Substitution	Appearance	Color	Aroma	Taste	Overall Appeal
0%	7.8 ± 1.2 ^{a}	8.2 ± 0.9 ^{a}	7.8 ± 1.0 ^{a}	8.2 ± 0.6 ^{a}	8.0 ± 0.8 ^{a}
25%	7.8 ± 1.5 ^{ab}	7.7 ± 1.6 ^{b}	7.7 ± 1.5 ^{a}	7.6 ± 1.7 ^{a}	7.6 ± 1.6 ^{ab}
50%	7.33 ± 1.5 ^{abc}	7.4 ± 1.5 ^{b}	7.0 ± 1.7 ^{b}	6.8 ± 1.7 ^{b}	7.0 ± 1.7 ^{bc}
75%	7.27 ± 1.6 ^{bc}	7.5 ± 1.7 ^{b}	6.8 ± 2.0 ^{b}	6.6 ± 2.0 ^{b}	6.8 ± 1.9 ^{c}
100%	6.8 ± 1.6 ^{c}	7.2 ± 1.6 ^{b}	6.7 ± 1.7 ^{b}	5.5 ± 2.0 ^{c}	5.5 ± 2.0 ^{d}

Figure 11. Consumer evaluations of the qualities of the various recipes on the 9-Point Hedonic scale. Only the 25% carrot substitution recipe was rated as highly as the original recipe. The superscript letters following each value indicate statistically significant differences ($p < 0.05$) in each quality tested.

powder, yielding approximately a 10% reduction in ingredient costs, 25% reduction in butter consumption, and about 7% reduction in calorie content, according to the data. This produces brownies with measurable differences in texture, but with no significant reduction in consumer enjoyment. Substituting 50% showed significantly reduced consumer appeal for most of the measured qualities, but, interestingly, showed no significant difference in two of the five measures of texture.

Further research is suggested to determine more precisely the point between 25% and 50% is the ideal substitution amount. Research into alternate methods for preparing and incorporating the carrot pulp into the recipes, to reduce the time and cost of the method used here, would also be beneficial. Finally, investigating the possibility of substituting carrot pulp for butter in other bakery products is suggested.

IV. CONCLUSION

We have shown that substituting powdered carrot pulp reconstituted with water at a ratio of 1:6 for butter in a brownie recipe is accepted by consumers as indistinguishable from the original recipe. It is recommended that bakeries substitute 25% reconstituted powdered carrot pulp for butter in their brownies as a way to reduce the unhealthy effects of butter consumption, increase the nutritional value, and reduce production costs of the brownies.

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