Full Title

Effect of Black Bean Puree as a Fat Replacer on the Physical, Textural and Sensory Acceptability of Gluten Free Brownies

Short Title

Black Beans Puree as a Fat Replacer in Gluten Free Brownies

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A. *Abstract*

Background and Aims

Energy-dense, fattening foods are major contributors to excess caloric intake and obesity. This study analyzes the replacement of black bean puree as a fat replacer in brownies and subsequent changes in physical, textural and sensory acceptability.

Methods

Gluten-free brownie recipe was compared with variations utilizing black bean puree as a substitution for shortening at 45% and 65%, using objective and textural analyses. Sensory acceptability was determined with 56 untrained panelists using a 9-point hedonic scale.

Results

Significant differences were observed while increasing substitution in viscosity, water activity and chewiness. Other textural and physical attributes were not significantly different. Sensory results showed no significant difference in overall liking, appearance, odor, taste or flavor between all variations, with all variations being liked slightly to moderately liked.

Conclusions

Gluten-free brownies prepared with up to 65% black bean puree were significantly lower in fat. Calories, trans fat and saturated fat levels were also reduced and fiber was slightly increased. Based on objective and sensory evaluations, it is observed that brownies with fat substituted with black bean puree may be an acceptable substitution with consumers. Further testing should be done with larger sample sizes, with potential future research testing variations in heights that are more typical of brownies.

B. ***Practical Uses***

With projections stating obesity is ever on the rise, fat replacers are one way to offer reduced fat and acceptable options in order to lower total caloric intake. Recent trends have substituted fat for nutrient dense, natural products in order to also increase nutrient density of products. While previous research has been done on peas and cannellini beans as fat replacers, black beans offer a different nutrient profile with ample phytonutrients, vitamins and minerals. Their use will also add protein, fiber and unsaturated fats. This experiment explores black beans as a fat alternative to help lower fat in baked products and improve nutrition.

C. ***Introduction and Background***

Obesity, and associated conditions such as cardiovascular disease and type 2 diabetes, affects a third of Americans and are the second leading cause of preventable deaths (Centers for Disease Control and Prevention 2014). The increasingly high rate of obesity over the last few decades is believed to be caused by a combination of factors. Genetically susceptible individuals respond to a culture in which there is increased availability of energy-rich foods and reduced frequency of energy expenditure. Decreased physical activity is due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization (World Health Organization 2011). Evolutionarily, humans have adapted to store fat in relatively large amounts, as starvation was a more common occurrence than overabundance. Technology and industrialization over the last century have improved quality of life by reducing barriers to food and decreasing manual labor, but the human body has not yet evolved to this often dubbed Westernized lifestyle. (Ogden *et all* 2012).

Previous research has shown that the consumption of "empty calories" not only gives excess calories, but also displaces other more nutrient dense foods, which results in weight gain as well as malnutrition (Poti *et all* 2013). Food items, like brownies, that are offered in schools often are not nutrient dense. For examples, calories in brownies are derived from about 30% fat (Briefel *et all* 2009). "Empty calorie" foods are linked to obesity as they contain energy-dense fats and sugars that have been shown to reduce satiety and increase over-eating, which promotes a positive energy balance and weight gain (Drewnowski 2004). The Dietary Guidelines for Americans concluded that diets low in energy density aid in weight loss and weight maintenance (Pérez-Escamilla *et all* 2012). Research indicates that replacing energy-dense foods with nutrient-dense foods can aid in the reduction of excess energy intake and could decrease the prevalence of obesity (Briefel *et all* 2009).

One way to reduce calories and fat consumption is to produce reduced-fat foods that are acceptable replacements to consumers. The use of fat replacers may play a pivotal role in decreasing total fat intake and total dietary energy (Position of the American Dietetic Association: Fat Replacers 2005). Using fat replacers has varying levels of success, as fat adds to sensory and physiological characteristics, such as flavor, mouth feel, moisture, odor and texture. It also contributes to appearance, palatability, texture, and creaminess (Akoh 1998). In baking, fats contribute to aeration, tenderness, flavor compounds, color and mouth feel (Murano 2003). Since fat traps air and aids in structural integrity (Hahn 1997), an acceptable fat replacer should maintain these functional and sensory characteristics (Borneo *et all* 2010).

Public demand for low-fat products remains high, with new research trending towards replacing fats and sugars with nutrient dense substitutes. Legumes have been shown to be

effective fat replacers in baked products that can decrease fat and increase nutritional value (Rankin *et all* 2000). Carbohydrate-based fat replacers act by stabilizing water in a gel-like matrix to simulate a creamy mouth feel that is similar to fat properties (Lucca *et all* 1994). Previously, cannellini bean and pea purees have been used as replacements for shortening in recipes for baked goods (Szafranski *et al.*, 2005, Romanchik-Cerpovicz *et al.*, 2009), but there has been little research on the use of black beans as a fat replacer. Black beans (Phaselous vulgaris), like other legumes, are nutrient dense per calorie, and provide many health benefits. One study concluded that for every 20g intake of legumes, the risk ratio of death was reduced by 6% in an older population (Solomons *et all* 1997). Another study showed that there was a significant inverse relationship between legume intake and risk of coronary heart disease (Bazzano *et all* 2001).

Black beans are abundant in protein, vitamins and minerals and are low in fat. They also contain several types of beneficial phytonutrient compounds such as anthocyanins, lignans, flavonoids and phytosterols, which can lower risk of osteoporosis, heart disease and certain cancers. They are rich in soluble and insoluble fibers and are good sources of vitamins and minerals such as copper, phosphorus, iron, manganese and magnesium. Unfortunately most Americans do not follow U.S. Dietary Guidelines that recommend 3 cups of beans a week (Raatz 2010).

With the substitution of shortening with black bean puree, low nutrient foods will gain the beneficial nutrients found in legumes. Additionally, the removal of shortening will reduce calorie-rich fat with a subsequent reduction in calories. Black beans will also replace saturated and trans fats with unsaturated fats. Dietary fiber will increase in products utilizing black beans,

but subsequent health benefits depend on level and amount of substitution. In previous research with peas and white cannellini beans as fat replacers, it was found that their addition did not induce noticeable changes in brownie characteristics (Szafranski *et al.*, 2005). While beans have a higher moisture content than shortening, it is thought their addition to foods with a high moisture content, such as brownies, allow for easy substitution. When pea puree was used under a 75% fat replacement, flavor, texture and tenderness remained acceptable in brownies (Romanchik-Cerpovicz *et al.*, 2009). Our project aimed to explore if black beans, with their similar but different composition, could also demonstrate similar properties and characteristics as previously used legumes in baked products.

D. ***Materials and Methods***

Black Beans

Black beans can be substituted for shortening on a one to one ratio. Black beans were drained and rinsed before being blended until creamy with only small flecks of skin visible. Pureed mixture was frozen between preparations and defrosted in order to minimize variation between black bean purees used.

Recipe

The brownie recipe obtained from the USDA Recipes for Schools was used in this study as the control recipe. (Table 1) Flour was substituted with sorghum flour and potato starch in order to make recipe gluten free. The addition of milk was added to all variations in order to increase moisture. Three variation recipes for brownies were included: (1) Control made with the modified gluten-free USDA recipe; (2) 45% substitution by replacing 45% of the shortening in the original recipe with black bean puree; (3) 65% substitution by replacing 65% of the

shortening in the original recipe with the black bean puree. All ingredients were purchased from local stores. Table 2 shows the ingredients and amounts used in each variation. The amount of shortening was the only ingredient that varied with the addition of black bean puree while all other ingredients remained consistent.

Preparation of Brownies

The brownies were made according to the same standardized procedure. Adjustments were made after initial testing by adding milk to increase moisture. For each recipe, shortening, sugar, salt and vanilla were mixed for 2 minutes on medium speed. Black bean puree was added during this step for the 45% and 65% variations. Eggs and milk were then added to the bowl and mixed for 3 minutes on medium speed. Dry ingredients were measured and stored in a separate bowl, which included sorghum flour, potato starch, xantham gum, cocoa and baking powder. These were added to the wet mix for 30 seconds on a low speed and then mixed for 1 minute on medium speed. 150 grams of batter were measured into each baking pan on an OHAUS-Explorer electronic scale. Pans containing all variations were then placed into the oven at 350° F for 20-30 minutes, periodically checking doneness with a toothpick. Brownies were then cooled before cutting and serving.

Preliminary Elimination Trials

After conducting preliminary trials, it was determined that the addition of milk was necessary to all variations to increase moisture. Sensory results from initial trials showed a preference for control, 45% and 65% substitution variations and so the 25% variation was eliminated from study.

Objective Testing

Line-spread test was used to measure viscosity of batter by placing a quarter cup of batter within a cylinder centered on a line-spread chart. Measurements were read after 2 minutes from four equally spaced axes to give an average value in centimeters of spread. Change in height was measured before and after baking to see percent increase in height and volume. Measurements were taken using a vernier caliper to measure height in millimeters. Hardness and chewiness were measured by the TA.XT 2texture analyzer and tested in triplicate. Water activity was calculated using an AquaLab water activity meter after brownies had cooled. Percent moisture was determined using the OHAUS (MB45) moisture analyzer by placing small samples on a pan which was then heated to 105 $^{\circ}$ C.

Subjective Testing

Sensory evaluations were conducted by untrained panelists (n=56) on the brownie control and black-bean variations using a 9-point hedonic scale to assess consumer overall acceptability. Panelists were presented scorecards (Figure 1) with ratings varying from “extremely dislike” to “extremely like” on five sensory attributes. These attributes include characteristics which are important factors influencing food choices - appearance, odor, flavor, taste and overall liking. Consumers were also asked to rank samples in order of liking. The hedonic scale is a reliable evaluation tool when assessing consumer preferences. Samples were randomly assigned corresponding numbers so as not to influence consumer perception with ordered numbers and placed on white-labeled paper plates (Figure 2). Sensory panel results were analyzed using Fizz software.

Nutrient Analysis

Nutritionist Pro software was employed to provide nutrient analyses on the brownie variations used in this study. Of primary focus were potential changes in total calories, total fat, saturated fat, and dietary fiber.

Results

Objective Results

Line spread results showed a significant difference in viscosity between control and both black bean variations (Figure 3 and 4). There was also a significant difference found between 45% and 65% variations (Figure 5). Changes in volume were not significantly different between control and 45% variation (Figure 6) or between control and 65% variation (Figure 7). There was no significant difference found in hardness between control and 45% variation (Figure 8) or control and 65% (Figure 9). No difference was seen in chewiness between control and 45% variation (Figure 10). However a significant difference was found between control and the 65% variation. (Figure 11)

Water Activity shows the reactivity of water in food. There was no significant difference found between control and the 45% and 65% variations. However the black bean variations tended to have a slightly higher water activity. Moisture analysis showed variations were inconsistent between trials. Samples were taken from various parts of the brownie, and as the different portions become more or less dry during the baking process this may have had an effect on testing. This may also be due to different cooking times on each day. Overall, moisture was slightly higher in variations with black beans, which is consistent with previous research (Wekwete *et all* 2008). Fiber in black beans binds to water which increases moisture (US Food and Drug Administration 2013). Surface of brownies did not show a large change in moisture

activity as can be see in Figure 12, though there are slightly more surface cracks visible on control. See table 3a-b for data.

Subjective Results

Results from the sensory evaluations revealed average scores between 6 and 7 across all sensory attributes for all brownie variations, indicating values between liked slightly and liked moderately for all attributes (Graph 8). No significant differences were seen between any of the variations in terms of appearance, odor, flavor, taste, and overall liking. This indicates that the substitution of black beans in place of shortening did not affect consumer acceptability. Control and 65% variation overall were slightly more liked in appearance, flavor, taste and overall liking but not at a significant difference.

Nutrient Analysis

Results from the nutrient analysis are seen in Table 4. The total calories for one serving of the control brownie are 200.7 kilocalories, for one serving of the 45% variation are 183.4 kilocalories, and 175.8 kilocalories for the 65% variation. The caloric decrease for the 45% brownie was 8.6% and for 65% was 12.4%. In the original recipe there was 25.92 grams of shortening used. In 45% replacement there was 16.83 grams used and in the 65% replacement there was 10.71 grams used, which contributed to decreases in calories seen in variations.

The substitution of black beans for shortening also decreased fat. Control had nearly 6 grams of fat per serving, whereas 45% had 3.6 grams and 65% had 2.6 grams. Fat decreased by 38.5% in 45% replacement and by over half at 55.6% in 65% replacement. According to Food and Drug Administration guidelines, both the 45% and 65% substitution products would be able to make the health claim that they are low in fat as they have less than 5 grams of fat. Also, if a

product has a 25% reduction in fat compared to a reference food it is possible to label it a reduced-fat food product. At a 38.5% and 55.6% decrease in fat respectively, our product would be labeled a reduced-fat and low-fat food (US Food and Drug Administration 2013). Saturated fat also decreased from 1.4 grams per serving down to .8 grams in the 45% replacement and .6 in the 65% replacement. All variations of brownies would be able to state they are low in saturated fat (US Food and Drug Administration 2013). Trans fat also dropped with control containing .7 grams, 45% containing .4 grams and 65% containing .2 grams.

Dietary fiber was low in original product at .267 grams per serving. At 45% this had increased to .367 grams and at 65% this had increased to .400 grams. This is a 49% and 80% increase in fiber in the product, but brownies would not drastically increase daily fiber intake. These levels are not significant enough to make health claims involving fiber for our product (US Food and Drug Administration 2013). It is important to note that sodium content may differ from analysis as beans were rinsed prior to blending.

Discussion

Brownies were shown to be acceptable to consumers when shortening was replaced by various percents of black bean puree. Initial height was inversely related to amount of black bean puree, though results showed no difference in final heights between products. Line spread showed that viscosity drastically increased with increasing amounts of black bean puree. Water activity and chewiness were slightly correlated with increased substitution. Other textural and objective properties did not show a significant difference.

Sensory evaluation results showed average scores between 6 and 7 across all sensory attributes for all brownie variations, indicating brownies were liked slightly to moderately. No

significant differences were seen between any of the variations in terms of appearance, odor, flavor, taste, and overall liking. Nutritionally, products with either level of substitution would able to be labeled low-fat and reduced-fat foods. Calories, trans fat and saturated fat levels were also reduced with increased levels of black bean puree. Fiber increased, but not at levels significant to daily recommendations.

Marketing

The finished product will be marketed as *BetterBrownieBites*: *Reduced-Fat Black Bean Brownies.* This will indicate the reduction of fat and its cause, as well as a smaller size. Brownies will weigh 40 grams. Brownies will be about 1.5 inches by 1.5 inches and 2 inches tall. Brownies could also be marketed in a more traditional wider and shorter shape, though additional testing should be done to ensure moisture levels are not reduced.

Two brownie squares will be placed on white glossy cardboard and surrounded by cellophane. Total package size width will be 3.5 by 2 inches, by 2 inches tall. Cellophane will a dark purple color with clear window showing product. On the lower left corner there will be a bean mascot, showing a black bean with a jovial smile and stick arms and legs as seen in Figure 13. The upper right corner will say “Reduced Fat Product! Low Saturated Fat!” The upper left corner will say “A Gluten-Free Product.” The bottom of the label will show that the package contains 80 grams of product with 2 brownies of 40 grams each. The nutrition facts label (Figure 13) will be located on the back of the package, with the ingredients listed below.

Product will have a suggested sale price of $2.99 and be located in dessert aisles as well as near checkout. Initially product will be tested in small health food stores, bodegas and delis. Next distribution will aim to expand to larger grocery and pharmacy chains. Product will be also

made available to gyms with an attached café. Expected customers are health conscious consumers of all age ranges. The bean mascot may appeal to children and nutrition-minded parents as well. Promotional booths at street fairs and fitness events handing out free samples will spark interest and brand recognition.

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Appendix

Table 1
Original recipe
Gluten Free Brownies
Serving size – 1/6th recipe or 40 grams
Source: USDA Recipes for Schools
Gluten Free Modification by: Alicia Galbo

Ingredient	Weight(g	Formula %	Bakers %
Shortening	25.92	0.08	76.24
Sugar	86.4	0.28	254.12
Salt	1.08	0.00	3.18
Vanilla	0.78	0.00	2.29
Sorghum Flour GF	34	0.11	100.00
Potato Starch	32	0.10	94.12
Xanthan Gum	0.2	0.00	0.59
Fresh Large Eggs	40.8	0.13	120.00
Cocoa	19.2	0.06	56.47
Milk	66	0.21	206.25
Baking Powder	1.7	0.01	5.00
Total	308.08	1	918.25

Instructions**:**

1. Cream shortening, sugar, salt and vanilla in mixer for 2 minutes on medium speed.
2. Add eggs and milk and beat for 3 minutes on medium speed.
3. Add sorghum flour, potato starch, xantham gum, cocoa, and baking powder. Mix for 30 seconds on low speed, then mix for 1 minute on medium speed. Batter will be very thick.
4. Spray pan (4” x 4” x 2”) with pan release spray.
5. Bake: Conventional Oven: 350° F for 20-30 minutes Convection oven: 300° F for 18-25 minutes
6. Cool.
7. Cut in 6 servings, weighing 40 grams each.

Table 2
Ingredients and amounts used for each variation are shown for 6 servings of gluten-free brownies. The amount of shortening in the recipes is the only ingredient that varied with the addition of black bean puree. All other ingredients remained consistent across recipes.

6 Servings			
		Variation 1	Variation 2
Ingredients	Control	45% replacement	% 65 replacement
Shortening	25.92	16.83	10.71
Sugar	86.4	86.4	86.4
Salt	1.08	1.08	1.08
Vanilla	0.78	0.78	0.78
Sorghum Flour GF	34	34	34
Potato Starch	32	32	32
Xanthan Gum	0.2	0.2	0.2
Fresh Large Eggs	40.8	40.8	40.8
Cocoa	19.2	19.2	19.2
Milk	66	66	66
Baking Soda	1.7	1.7	1.7
Black Bean Puree		9.09	15.21

Figure 1.

Appearance

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike Very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Taste

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike Very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Flavor

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike Very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Palatability

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike Very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Overall Acceptability

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike Very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Please rank the brownies in the order of liking:

_____	_____	_____
Most	Moderately	Least

Figure 2.
Samples as presented to panelists

Table 3a-b
Collection of raw data, averages and standard deviation for all variations.

Variation	Line Spread Test (cm)	Initial Height (mm)	Final Height (mm)	% Change in Volume
Control	4.75			
	5.25	19.8	45.4	1.29
	2	18.9	43.9	1.32
	0.5	21.5	40.7	0.89
	2	21.4	33.1	0.55
	3.25	26.1	30.2	0.16
	1.5	46.7	46.7	0.57
	0.5	47.2	47.2	0.68
	1.25	52.9	52.9	1.16
Average	2.625	31.8125	42.5125	0.8275
Std	1.732050808	14.44956129	7.570136345	0.410844079
CV	0.659828879	0.454210178	0.178068482	0.496488313
45%	7			
	7.5	20.6	48.9	1.09
	10.75	21.3	42.8	1.01
	8.5	20.1	42.9	1.13
	10.5	17.7	41.3	1.33
	9.25	19.1	39.8	1.08
	6.25	40.4	40.4	0.67
	10.5	42.3	42.3	0.91
	9.25	36.1	36.1	0.56
Average	9.9375	27.2	41.8125	0.9725
Std	1.639359631	10.46149402	3.616801073	0.252119586
CV	0.164967007	0.384613751	0.086500474	0.259248932
65%				
	11.25	21.7	42	0.94
	12.25	22.3	44.2	0.98
	15.75	19.4	45.5	1.35
	15.5	18.2	41.1	1.26
	16.25	16.8	42.4	1.52
	15.75	21	35.6	0.7
	15.25	20	45	1.25
	16.25	20.5	39.8	0.94
Average	14.78125	19.9875	41.95	1.1175
Std	1.919995815	1.823213411	3.22578894	0.269960315
CV	0.129894009	0.091217682	0.076896041	0.241575226

Variation	Moisure Ai	Water Activ	Hardness	Chewiness
Control				
	31.96	0.77	1,441.97	46.53
	30.17	0.77	890.66	47.47
	31.34	0.859	1,147.34	43.59
			1,475.16	41.24
			1,748.48	43.23
			1,855.61	44.65
			2,177.58	46.58
			1,834.80	46.97
			1,952.38	50.04
Average	31.15667	0.7996667	1,613.78	45.5888889
Std	0.908974	0.0513842	410.365549	2.65708226
CV	0.029174	0.064257	0.25428911	0.05828355
45%				
	27.24	0.848	2,097.56	45.53
	26.82	0.789	2,797.10	43.19
	34.16		527.31	44.46
			848.49	48.28
			940.25	51.79
			928.58	54.24
			2,051.62	47.53
			1,108.16	46.8
			855.30	47.09
Average	29.40667	0.8185	1,350.49	47.6566667
Std	4.12186	0.0417193	768.297512	3.47449277
CV	0.140168	0.0509704	0.56890465	0.07290675
65%				
	24.05	0.847	1,776.52	49.69
	27.87	0.854	1,872.79	48.43
	35.44		1,852.49	48.95
			2,105.41	46.46
			2,458.10	47.87
			2,544.35	50.91
			715.02	48.97
			613.35	50.49
			645.87	50.5
Average	9.706667	0.8505	1,620.43	49.1411111
Std	5.796973	0.0049497	767.802944	1.43491676
CV	0.597216	0.0058198	0.47382569	0.02919993

Figure 3
Line spread t-test between Control and 45% variation

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -7.5681
95% confidence interval of this difference: From -10.7283 to -4.4078

Intermediate values used in calculations:
t = 5.1044
df = 15
standard error of difference = 1.483

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Review your data:

Group	Group One	Group Two
Mean	2.4444	10.0125
SD	1.7401	4.0609
SEM	0.5800	1.4357
N	9	8

Figure 4
Line spread between control and 65% variation

P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -12.4479
95% confidence interval of this difference: From -14.3351 to -10.5607

Intermediate values used in calculations:
t = 14.0588
df = 15
standard error of difference = 0.885

Learn more:
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Review your data:

Group	Group One	Group Two
Mean	2.3333	14.7813
SD	1.7321	1.9200
SEM	0.5774	0.6788
N	9	8

Figure 5
Line spread between 45% and 65% variations

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -12.4479
95% confidence interval of this difference: From -14.3351 to -10.5607

Intermediate values used in calculations:
t = 14.0588
df = 15
standard error of difference = 0.885

Learn more:
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Review your data:

Group	Group One	Group Two
Mean	2.3333	14.7813
SD	1.7321	1.9200
SEM	0.5774	0.6788
N	9	8

Figure 6
Changes in volume between control and 45% variation

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.2564
By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -0.2039
95% confidence interval of this difference: From -0.5750 to 0.1672

Intermediate values used in calculations:
t = 1.1872
df = 13
standard error of difference = 0.172

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

Review your data:

Group	Group One	Group Two
Mean	0.8275	1.0314
SD	0.4108	0.2043
SEM	0.1453	0.0772
N	8	7

Figure 7
Changes in volume between control and 65%

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.1115
By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -0.3154
95% confidence interval of this difference: From -0.7144 to 0.0837

Intermediate values used in calculations:
t = 1.7074
df = 13
standard error of difference = 0.185

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

Review your data:

Group	Group One	Group Two
Mean	0.8275	1.1429
SD	0.4108	0.2811
SEM	0.1453	0.1063
N	8	7

Figure 8
Hardness between control and 45% variation

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.5152
By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals 201.2260
95% confidence interval of this difference: From -442.3164 to 844.7683

Intermediate values used in calculations:
t = 0.6665
df = 15
standard error of difference = 301.927

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

Review your data:

Group	Group One	Group Two
Mean	1613.5122	1412.2862
SD	410.1280	796.9311
SEM	136.7093	281.7577
N	9	8

Figure 9
Hardness between control and 65% variation

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.6529
By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -128.68
95% confidence interval of this difference: From -726.37 to 469.00

Intermediate values used in calculations:
t = 0.4589
df = 15
standard error of difference = 280.412

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

Review your data:

Group	Group One	Group Two
Mean	1613.44	1742.13
SD	410.48	721.85
SEM	136.83	255.21
N	9	8

Figure 10
Chewiness between control and 45% variation

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.1887
By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -2.1386
95% confidence interval of this difference: From -5.4489 to 1.1717

Intermediate values used in calculations:
t = 1.3770
df = 15
standard error of difference = 1.553

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

Review your data:

Group	Group One	Group Two
Mean	45.5889	47.7275
SD	2.6571	3.7178
SEM	0.8857	1.3144
N	9	8

Figure 11
Chewiness between control and 65%

Unpaired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.0059
By conventional criteria, this difference is considered to be very statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -3.3824
95% confidence interval of this difference: From -5.6337 to -1.1311

Intermediate values used in calculations:
t = 3.2023
df = 15
standard error of difference = 1.056

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals. Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists*.

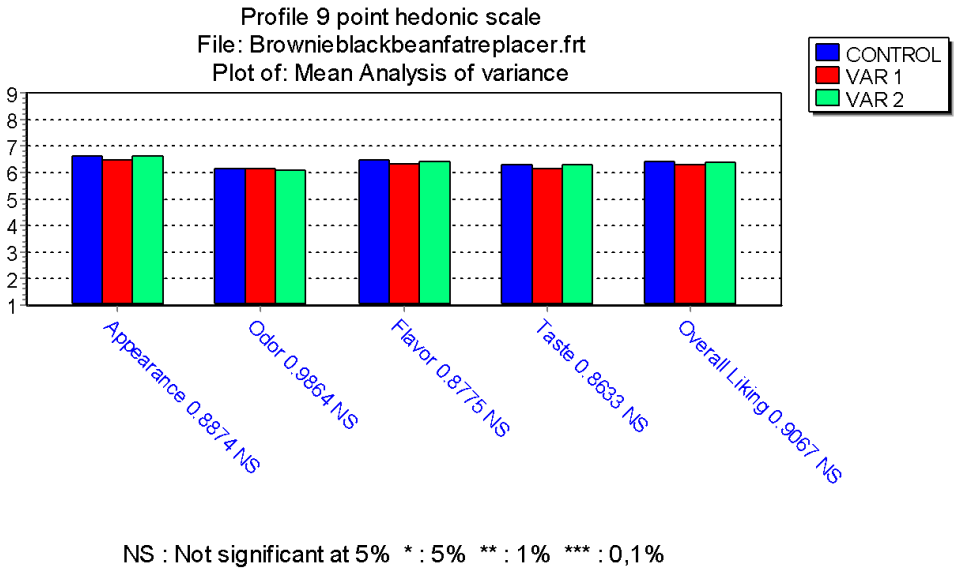
Review your data:

Group	Group One	Group Two
Mean	45.5889	48.9713
SD	2.6571	1.4340
SEM	0.8857	0.5070
N	9	8

Figure 12.
Brownies after baking, with slight variations seen in surface. Control is seen at front of photo followed by 45% and 65%.

Graph 1

Summary of sensory analysis results on the control, 45%, and 65% recipes from the trials conducted using a 9-point hedonic scale with untrained panelists.



NS : Not significant at 5% * : 5% ** : 1% *** : 0,1%

Table 4.
Nutrient Analysis between variations

Serving size 1 Black Bean Brownie			
Nutrition Facts	**Control**	**Variation 1: 45% Replacement**	**Variation 2: 65% Replacement**
Calories:	200.718	183.447	175.777
%Decrease (Calories):	---	8.60%	12.43%
Total Fat:	5.931 g	3.648 g	2.633 g
%Decrease (Fat)	---	38.49%	55.61%
Protein:	2.099 g	2.303 g	2.393 g
Carbohydrates:	35.590 g	36.134 g	36.376 g
Saturated Fat:	1.441 g	0.871 g	0.617 g
Trans Fat:	0.672 g	0.369 g	0.235 g
Cholesterol:	23.873 mg	23.873 mg	23.873 mg
Vitamin A (IU):	41.128 IU	41.266 IU	41.327 IU
Vitamin C:	0.019 mg	0.019 mg	0.019 mg
Iron:	0.957 mg	1.004 mg	1.025 mg
Calcium:	223.904 mg	224.502 mg	224.767 mg
Sodium:	215.235 mg	215.166 mg	215.136 mg
Dietary Fiber:	0.267 g	0.367 g	0.400 g
Soluble Fiber:	0.00 g	0.039	0.066
Insoluble Fiber:	0.00 g	0.610	0.102

Figure 13
Product mascot

Figure 14
BetterBrownieBites: *Reduced-Fat Black Bean Brownies food label*

Nutrition Facts

Serving Size 1 Brownie (40g)
Serving Per Container 2

Amount Per Serving

Calories 176	Calories from Fat 24
	% Daily Values*
Total Fat 2.6g	**4%**
Saturated Fat 0.6g	**3%**
Trans Fat 0.2g	
Cholesterol 24mg	**8%**
Sodium 215mg	**9%**
Total Carbohydrate 36g	**12%**
Dietary Fiber 0.4g	**2%**
Sugars 12g	
Protein 2.4g	**5%**

Vitamin A 0.8% • Calcium 22.5%

Iron 5.6%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2400mg	2400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g