Brown Rice Syrup: Effect of a Natural Sugar Substitute on Texture, Moisture and Consumer Preference in Brownies

453 Research Project
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Abstract:

Over the years there has been an increase in consumption of simple carbohydrates such as the sugars found in soft drinks, baked goods and candies. These simple carbohydrates are broken down and digested quickly by the body creating a rapid increase in glucose in the blood. This is due to the high glycemic index rating of these simple carbohydrates. The uncontrolled blood glucose levels lead to various health complications. By partial or full replacement of the simple carbohydrate of sugar to a more complex carbohydrate such as those found in brown rice syrup can slow the digestion of the sugars and help control blood glucose levels. Brown rice syrup has more nutritional value and is healthier for the consumer’s body than sugar. In this experiment brown rice syrup was used as a full and partial replacement to sugar in brownies. Three brownie variables were created using 100% sugar, 50% sugar and 50% brown rice syrup, and 100% brown rice syrup and were tested objectively for force by the texture analyzer, moisture by the water activity system and subjectively by a taste panel for preference and sweetness level. The texture analyzer with cylinder attachment showed that the 100% sugar had the highest force value followed by the 50% sugar and 50% brown rice syrup, and 100% brown rice syrup. The levels for the water activity were all very close in value but the 100% brown rice syrup did produce the highest level. When tasted by the panelist the traditional brownie was favored by 60% of the panelist but the 50% sugar and 50% brown rice syrup brownie followed closely behind with 40% of the panelist favoring it the most. Brown rice syrup is about half as sweet as sugar so it was not surprising that the 100% sugar was ranked the sweetest and the 100% brown rice syrup was ranked the least sweet. This experiment proved that a partial replacement of sugar with brown rice syrup in brownies can be desirable by some consumers because of the increase in moisture and texture while still retaining a sweet flavor.

Introduction:

Consumption of simple carbohydrates such as highly refined sugars has increased over the years outweighing the consumption of complex carbohydrates. This elevated intake of sugary foods and beverages such as soft drinks and sweets can lead to harmful effects on the body. Consuming an over abundance of sugar can cause problems such as tooth decay, weakened immune system and is linked to diabetes, obesity and cardiovascular disease (Cheney 1998). Many food companies have begun using artificial sweeteners in their products in effort to produce a sweet taste without the harmful health effects. However, there are some consumers who still have a sweet tooth but would rather not consume an artificial product. Luckily for those consumers there are many alternatives for obtaining a sweet product while still being health conscience. Natural sugars, such as those found in agave, barley malt syrup,
date sugar and brown rice syrup, contain more complex carbohydrates which are absorbed slower and are less likely to disrupt blood sugar levels.

Brown rice syrup is a natural sugar that can be used in cooking and baking. Brown rice syrup is made by “combining cooked brown rice with dried sprouted barley and culturing the mixture until malt enzymes convert some of the rice starch into maltose (about 45 percent) and glucose (about 3 percent) (Cheney 1998).” The syrup contains more complex carbohydrates than refined white sugar and also contains B vitamins especially vitamin B6. The chemical structures of maltose and glucose can be seen in figures 7 and 8. Foods such as brown rice syrup with higher percentages of complex carbohydrates have a lower glycemic index which help in stabilizing blood sugar levels.

Glycemic index is “the blood glucose response of a given food compared to a standard (Wardlaw and other 2007 pg 171).” The glycemic index provides a ranking for system for foods based on their effect on blood glucose levels. High glycemic foods are considered to be above 61 on the ranking scale, medium glycemic foods are 40 to 60 and low glycemic foods are less than 40 (Bark 2002). Foods with a lower to medium glycemic index, such as the brown rice syrup, will not elicit such a large release of insulin which leads to harmful effects on the body such as high blood triglycerides, increased fat deposits, increased blood clotting, diabetes and cardiovascular disease. According to “Diabetes Care”, poor glycemic control is a risk factor for low high density lipoproteins (HDL) in type 2 diabetes which is caused by obesity and weight gain. If these patients could control their glycemic index by consuming lower glycemic foods such as the complex carbohydrates in brown rice syrup they would be able to increase their HDL and control their diabetes. Brown rice syrup not only helps to control blood glucose levels due to its lower glycemic index but it also contains beneficial B vitamins.

According to Katherine Tucker, Ph. D in Perspective in Nutrition, a survey showed that a large proportion of older adults have inadequate intake of B vitamins including B6. Vitamin B6 is an important water soluble vitamin in not only protein metabolism and immune function but also in reducing cardiovascular disease and stroke. Figure 9 depicts the activated form of vitamin B6 pyridoxal 5’-phosphate (PLP). The activated PLP from vitamin B6 is involved in methionine metabolism to clear homocysteine from the bloodstream. According to the Journal of Nutrition, if homocysteine levels are elevated in the blood it can lead to cardiovascular disease, fatal coronary heart disease and stroke (Nijhout and others 2009). The B vitamins and complex carbohydrates found in brown rice syrup provide several health benefits such as reducing disruption in blood glucose levels and reducing risk for cardiovascular disease.

Brown rice syrup has been added to granola bars and other health foods to increase nutritional value. It can also be added to baked goods such as brownies in replacement of white granulated to sugar to achieve the same nutritional benefits. A total or partial replacement of white granulated sugar with brown rice syrup would decrease its glycemic index which would help to stabilize blood glucose levels and reduce the risk of diabetes and
cardiovascular disease. The B vitamins found in the syrup would enrich the brownies helping to reduce the risk for cardiovascular disease, heart disease and stroke.

In this experiment brownies were created using various concentrations of white granulated sugar and brown rice syrup. The control was created using 100% white granulated sugar and two variables were created by partial or full replacement of the sugar. One variable contained 50% white granulated sugar and 50% brown rice syrup and the other was made with 100% replacement by brown rice syrup. The baking time, temperature and other ingredients were kept constant with all variables unless otherwise noted. After baking the brownies were tested based on consumer preference and sweetness level, force by a stable micro systems texture analyzer and moisture by a water activity system.

Methods:

In the experiment three types of brownies were made. One with 100% sugar, a second with 50% sugar and 50% brown rice syrup and a third with 100% brown rice syrup. The experiment was recreated three times. Each trial was completed before the next one was started and adjustments were made as needed. The recipe below for the first trial was a recipe made specifically for brownies with brown rice syrup and can be found on Debra Lynn Dadd’s website on natural sweeteners.

Recipe:

100% brown rice syrup

71 g butter
115 g brown rice syrup
128 g unsweetened cocoa powder
4.75 g vanilla
2 eggs
115 g flour
.6 g salt

50% sugar and 50% brown rice syrup

71 g butter
57.5 g brown rice syrup
57.5 g white sugar
128 g unsweetened cocoa powder
4.75 g vanilla
2 eggs
115 g flour
.6 g salt
100 % sugar  
71 g butter 
115 g white sugar 
128 g unsweetened cocoa powder 
4.75 g vanilla 
2 eggs 
115 g flour 
.6 g salt  

Procedure: 
Preheat oven to 177 degrees C. In a large saucepan, melt the butter completely over low heat. Stir in variable of brown rice syrup or white sugar. Stir in the cocoa a little at a time, whisking in each addition until blended. Remove from heat and cool for about 15 minutes. Blend in eggs one at a time. Add vanilla and salt. Stir in flour a little at a time. Spread batter into a greased 8x8-inch baking pan. Bake for 30 minutes.  
The brownies were allowed to cool for 15 minutes. They were then cut and prepared for the subjective taste panel and the objective testing by the texture analyzer and water activity system. The taste panel was ten college students at Purdue University. The taste panel received a numbered sample of each brownie and the score card that is present below. Sample 243 was the 100% sugar, 592 was the 50% brown rice syrup and 50% sugar and 469 was the 100% brown rice syrup.  

**Sensory Evaluation of Brownies**  
Rank the samples (469, 243, 592) in order of preference, one being the most desired and three being the least desired.  
469__________  
243__________  
592__________  

Rate samples (469, 243, 592) in descending order for sweetness on the six-point scale below.  
(1) ______________  
(2) ______________  
(3) ______________  
(4) ______________  
(5) ______________  
(6) ______________
Objective test were ran to measure the texture by force in grams and the moisture level by water activity. The stable micro systems texture analyzer was used. The machine was first turned on the texture analyzer program was opened. The probe attachment was used to test all samples in all three trials and the cylinder attachment was used to test the samples in the last trials. A new graph was loaded and the T.A. product setting chosen was “cookie.” Each sample was then placed under the probe and a quick test run was ran. Three test were ran on each sample during each trial of the experiment. The results can be seen for each trial in tables 1, 2 and 3 and are depicted as graphs in figures 1, 2 and3. The water activity system was used to measure the free water in the food. The equation for the free water in food is $Aw = \frac{\text{water vapor pressure of the food}}{\text{water vapor pressure over pure water}} = \% \text{ equilibrium relative humidity.}$ The machine was turned on and allowed to warm up for 15 minutes. A sample of each variable of brownie was placed in a sample dish. The dish was loaded into the draw, closed and turned from “OPEN/LOAD” to “READ.” The results from each trial can be seen in tables 4 and 5 and graphs depicting these values can be seen in figures 4 and 5.

The taste from trial one of the experiment was undesirable as they were too chocolaty and dense. A new brownie recipe for traditional brownies was found and used for trial two. Below is the recipe used for trial two and three.

**100% Brown Rice Syrup**

85.4 g unsweetened cocoa
71.175 g butter
229.92 g brown rice syrup
2.373 g vanilla
1.186 g salt
76.563 g flour
2 eggs

**50% sugar and 50% Brown Rice Syrup**

85.4 g unsweetened cocoa
71.175 g butter
114.96 g brown rice syrup
114.96 g sugar
2.373 g vanilla
1.186 g salt
76.563 g flour
2 eggs
100% sugar
85.4 g unsweetened cocoa
71.175 g butter
229.92 g sugar
2.373 g vanilla
1.186 g salt
76.563 g flour
2 eggs

The method for preparing the samples for trial two were the identical as in trial one. The same objective taste panel survey was used to test consumer preference as in trial one and the subjective test were ran as they were in trail one also. After allowing all samples to cook for 30 minutes the 50% brown rice syrup and 50% sugar along with the 100% brown rice syrup had not fully cooked and were very gooey. Those two samples were allowed to cook for 15 additional minutes which did not cause them become fully cooked either. For the third and final trial to compensate for the undercooked brownies from trial two 76.563 addition grams of flower were added to the 50% brown rice syrup and 50% sugar along with the 100% brown rice syrup. This was added to make up for the extra moisture from the brown rice syrup in those two samples which may have prevented them from fully cooking. Trial 3 method was identical to the first trial and the same subjective taste panel was used to test consumer preference and the objective test were also ran. During the texture analysis of the third trial in addition to testing with the probe the cylinder attachment was used. The cylinder attachment is a more accurate test when testing flat products such as brownies. The results can be seen in table 3 and are depicted in graph form in figure 3. After adjusting the recipes for each trial, trial three produces the most desirable taste and for purposes of this experiment the subjective taste panel results from this trial will be used.

Discussion:

Tables 1 and 2 show the numerical values for the texture analyzer when using the probe attachment and figures 1 and 2 depict those values as a graph. In all three trials and the average of the three trials showed that the brownie made with 50% sugar and 50% brown rice syrup had the highest values for force. The average of all the trials showed that the brownie with 100% brown rice syrup had the lowest value for force. When the cylinder attachment was used which is believed to be the more accurate device for this experiment the 100% sugar had the highest force value followed by the 50% sugar and 50% brown rice syrup and the least for by the 100% brown rice syrup. These results, as shown in table 3 and figure 3, depict what was expected because the brown rice syrup was a liquid and thus would create a softer brownie and result in a lower force from the texture analyzer.
Table 4 and 5 show the individual trial results and their average results from the water activity system respectively. They are also depicted as graphs in figures 4 and 5. The water activity system measured the free water in the food. The equation for the free water in food is

\[ Aw = \frac{\text{water vapor pressure of the food}}{\text{water vapor pressure over pure water}} = \% \text{equilibrium relative humidity.} \]

All the values were very close for all three variables of the brownies. The variable with 100% brown rice syrup did average to be slightly higher than the other two variables. It is expected that the brownie with 100% brown rice syrup would have the highest water activity because the brown rice syrup was a liquid and would create more free water in the product.

After completing all trials of the experiment it was concluded that trial 3 produced the highest quality and taste for the brownies and was the trial used for the subjective consumer panelist testing. There was an overwhelming agreement between all the panelists that the brownie with 100% brown rice syrup was least preferred as seen in table 6 and figure 10. The traditional brownie made with 100% sugar was the most preferred with 60% of the panelist ranking it as the most desired but it was followed closely by brownie with 50% sugar and 50% brown rice syrup with 40% of the panelist ranking it as their most desired. Table 7 and figure 11 show the results from the 6 point rating based on sweetness of the brownies. When ranking the brownies on a 6 point descending scale for sweetness the 100% sugar was rated the sweetest with an average score of 1.7 followed by the 50% sugar and 50% brown rice syrup with an average score of 3.9 and least sweet was the 100% sugar with an average score of 5.5.

According to the PCC natural market webpage on natural sweeteners, brown rice syrup is about half as sweet as white sugar which would justify the panelist ranking on the sweetness of the brownies. Figure 6 depicts the effect of water activity on the force of the brownie from the texture analyzer. This figure shows that as water activity increases there is a decline in force.

This experiment proved that a partial replacement of sugar with brown rice syrup in brownies can be desirable by some consumers because of the increase in moisture and texture while still retaining a sweet flavor. In future experiments other forms of brown rice syrup, such as a powder form, could be used and tested against the traditional sugar brownie or liquid brown rice syrup brownie. Other natural sweeteners such as barley malt syrup or agave could also be tested to see if a greater replacement of sugar could be achieved without compromising the sweetness, moistness or texture of the brownie.
Results:

Table 1: Experimental effect of brown rice syrup vs sugar concentrations on force of probe by trial

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Force (g) Trial 1</th>
<th>Force (g) Trial 2</th>
<th>Force (g) Trial 3</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sugar</td>
<td>197.4</td>
<td>42.9</td>
<td>134.8</td>
<td>77.7</td>
</tr>
<tr>
<td>50% sugar &amp; 50% brown rice syrup</td>
<td>246.9</td>
<td>69.7</td>
<td>155.8</td>
<td>88.6</td>
</tr>
<tr>
<td>100% brown rice syrup</td>
<td>204.4</td>
<td>19.7</td>
<td>81.9</td>
<td>92.9</td>
</tr>
</tbody>
</table>

Table 2: Overall average of experimental effect of brown rice syrup vs sugar concentration on force by probe

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Force (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sugar</td>
<td>125.0</td>
</tr>
<tr>
<td>50% sugar &amp; 50% brown rice syrup</td>
<td>157.4</td>
</tr>
<tr>
<td>100% brown rice syrup</td>
<td>101.3</td>
</tr>
</tbody>
</table>

Table 3: Experiment effect of brown rice syrup vs sugar concentration on force by cylinder

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Force (g)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sugar</td>
<td>507.8</td>
<td>65.02</td>
</tr>
<tr>
<td>50% sugar &amp; 50% brown rice syrup</td>
<td>334.7</td>
<td>75.45</td>
</tr>
<tr>
<td>100% brown rice syrup</td>
<td>320.8</td>
<td>104.55</td>
</tr>
</tbody>
</table>

Table 4: Experimental effect of type of sugar in brownies on water activity by trial

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Aw Trial 1</th>
<th>Aw Trial 2</th>
<th>Aw Trial 3</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sugar</td>
<td>.785</td>
<td>.438</td>
<td>.685</td>
<td>.154</td>
</tr>
<tr>
<td>50% sugar &amp; 50% brown rice syrup</td>
<td>.795</td>
<td>.296</td>
<td>.759</td>
<td>.278</td>
</tr>
<tr>
<td>100% brown rice syrup</td>
<td>.802</td>
<td>.608</td>
<td>.772</td>
<td>.105</td>
</tr>
</tbody>
</table>

Table 5: Overall average of experimental effect of type of sugar in brownie on water activity

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Aw</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sugar</td>
<td>.651</td>
</tr>
<tr>
<td>50% sugar &amp; 50% brown rice syrup</td>
<td>.617</td>
</tr>
<tr>
<td>100% brown rice syrup</td>
<td>.728</td>
</tr>
</tbody>
</table>
Table 6: Result from trial 3 taste panel on preference of brownie ranked from one to three with one being most desired and three being least desired

<table>
<thead>
<tr>
<th>Sample</th>
<th>Panelist Ranking</th>
<th>Average ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>243, 100% sugar</td>
<td>1,1,1,1,1,2,2,2</td>
<td>1</td>
</tr>
<tr>
<td>592, 50% sugar and 50% brown rice syrup</td>
<td>1,1,1,1,1,2,2,2</td>
<td>2</td>
</tr>
<tr>
<td>469, 100% brown rice syrup</td>
<td>3,3,3,3,3,3,3,3,3,3,3,3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 7: Average results from trial 3 taste panel on level of sweetness using a 6 point scale with 1 being the sweetest and 6 being the least sweet

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average ranking of sweetness</th>
</tr>
</thead>
<tbody>
<tr>
<td>243, 100% sugar</td>
<td>1.7</td>
</tr>
<tr>
<td>592, 50% sugar and 50% brown rice syrup</td>
<td>3.9</td>
</tr>
<tr>
<td>469, 100% brown rice syrup</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Figure 1:

**Experimental effect of type of sugar in brownies on force probe by trial**
Overall average of experimental effect of type of sugar in brownies on force of probe

Experimental Effect of type of sugar in brownies on force cylinder
Figure 4:

Experimental effect of type of sugar in brownies on water activity by trial

Figure 5:

Overall average of experimental effect of type of sugar in brownie on water activity
Figure 6:

![Graph showing the experimental effect of water activity on force of brownies by cylinder.](image)

**Experimental effect of water activity on force of brownies by cylinder**

Figure 7:

Chemical structure of maltose (Zamora 2005)

Figure 8:

Chemical structure of glucose (Zamora 2005)
Figure 9:

Chemical structure of activate form on vitamin B6 (Jiang 2009)

Figure 10:

Taste panelist who ranked brownie sample as being most desired
Average sweetness of brownies ranking on a 6 point scale in descending order.
References


Websites


