Research Paper

Honey as Replacement for Sucrose in Baked Products

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Abstract

To determine whether honey can be used to replace sucrose or table sugar in baking, we used honey crystals in a standardized snicker doodle cookie recipe. We compared a control recipe of 100% sucrose to 100% honey replacement of sucrose and 75% honey replacement of sucrose. To perform this comparison we tested the three samples of cookies using objective tests of wettability and a modified line spread test. We also had twenty five participants evaluate in a blind taste test and all three samples and rate them based hardness, mouth-feel, and overall acceptability. The results of this subjective tests showed a favoritism toward the 75% honey replaced cookies, although the objective tests did not predict this outcome. From these findings, it was concluded that honey can be used as a replacement for sucrose using only 75% of required sucrose amount and still be accepted.

Introduction

Unhealthy diets, physical inactivity, and smoking, when left alone can lead to weight gain and obesity. Cardiovascular disease (CVD) and diabetes are diseases that have become worldwide epidemics, due to the rise in obesity and overweight in the population. CVD is responsible for over 16 million deaths per year, worldwide or 30% of all documented deaths worldwide. These deaths can be prevented by making interventions in unhealthy lifestyle choices ("Affluence and the," 2005). In 2010, there was an estimated 285 million people in the world's adult population that live with diabetes, this is roughly 6.4%. By 2030, these numbers are expected to grow to 438 million adults, or 7.8% of the adult population ("Diabetes facts," 2011).

When designing our own research project, we were looking for a table sugar replacement that contained nutrients and fewer calories, to help make an intervention in unhealthy diets. Table sugar, or sucrose, is a simple carbohydrate high in calories and contains no beneficial

nutrients. Although the honey crystals are not ounce for ounce less calories than sucrose, we believe that because honey is sweeter, less will be needed and therefore the overall product will contain fewer calories. **Hypothesis**: In our research we sought to prove that not only can honey crystals be substituted for sugar in a baked product, but less honey crystals are needed.

Although not widely known, honey has been used therapeutically since the advent of medicine. Archeologists have found evidence of honey use in ancient societies such as the Babylonians, Egyptians, and Sumerians. There are 300 different types and counting of honey for sale in market places and each of these types offers a slightly altered mineral and vitamin content (Aghasizadeh et al, 2008).

Literature Review

In our research, we chose two experiments performed on rats and two studies performed on humans, all of which sought to find the health benefits of consuming honey compared to sucrose. Each study examined honey's effect on weight management, reduction in risk for and management of diabetes and cardiovascular disease.

One study we found, "The effect of honey compared to sucrose, mixed sugars, and a sugar-free diet on weight gain in young rats" proved interesting. The study was performed on 40 rats, each was given a solution modeled after the typical New Zealand diet (as the study was done in New Zealand). Of the total calories given, 15-16% came from protein, 35% came from fat, and the final 45-47% came from carbohydrate. Their diets contained either no sugar, sucrose, mixed-sugars, or honey. All diets contained the same amount of added nutrients, minerals, and water. All rats were weighed before the start of the trial and were only allowed into the trial if they were at normal weight. Throughout the trial, they were weighed every 7 days and a final weight was taken. Blood samples were taken before and after the trial. Of the rats that were on

the honey diet, they had an average of 138% weight gain. Compared to the sugar-free diet's average weight gain of 137%, the sucrose diet with an average 155% weight gain, and the mixed sugar diet with an average 151% weight gain, the rats on the honey diet averaged one of the lower weight gains similar to the sugar-free group. There was no significant difference between the honey group and any other sugar group when measuring total calorie intake. The total body fat percentage was also measured, only to find no significant decrease in the honey group from any other group. Lipid profile and HgbA1C were also measured; however, no significant trend was indicated. The study concluded that honey may be a good replacement for sugar in food and beverages because it can provide sweetness without the same weight gain as sucrose, (Chepulis, 2007). However, this study was conducted over a relatively short period of tme and a longer lasting study may be needed for further conclusions

Another New Zealand study called, "The Long-Term Effects of Feeding Honey Compared with Sucrose and a Sugar-Free Diet on Weight Gain, Lipid Profiles, and DEXA Measurements in Rats" was performed in 2007 and sought to further these conclusions in a longer term study. Honeydew honey with high antioxidant content was used in this study. Forty five rats, all of similar weights, were randomly separated into 1 of 3 groups according to the diets of this experiment. The three diets prepared either contained no sugar, 7.9% sucrose, or 10% honey and all had a minimum of 5% water. The diets formulated represented a typical New Zealand diet, the same as mentioned in the previous study. The study took place over a year, and since this was not enough time for any long term diseases to develop, the researchers used cooking oil for all fat content to promote oxidative stress. Researchers ensured control of measuring and analyzing each rat's influencing factors, i.e. diet, temperature, exercise equipment, water, etc. The effect of honey on weight gain in adult rats confirmed the results of

the previous study. Percentages of weight gain in honey-fed rats were similar to those of rats fed the sugar-free diet, and was significantly reduced by 23.4% than rats fed a sucrose diet. Blood sugar and Hemoglobin A1c levels were reduced in rats fed a honey diet compared with those fed a sucrose diet. High Density Lipoprotein levels were shown to be 16% to 21% higher in honey fed rats than those fed sucrose or sugar-free diets. There were a small number of differences in body composition revealed by full body DEXA scans between the 3 diets. Bone mineral composition was higher in sucrose fed rats than sugar-free diets, while honey-fed rats showed a slight but significant increase in whole body bone mineral density (BMD) compared with the rats on a sugar-free diet. This study proved that there are benefits to consuming honey over a prolonged period of time, as weight gain was substantially reduced, blood sugar was lowered, and HDL levels were increased. Diet has lesser effect on rodent biochemical markers than humans; therefore studies similar to those performed on the rats should be repeated on humans to prove more conclusively these conclusions **(**Chepulis & Starkey, 2007).

Another study called "The Effects of natural honey consumption in diabetic patients: an 8 week randomized clinical trial" was performed in Iran that investigated the effects of natural honey on weight gain as well as blood biochemical markers of diabetic subjects. Researchers in Iran were interested in the idea of sugar replacements for people with diabetes. The researchers thought to use honey as a replacement due to its composition of mainly fructose and glucose. Fructose is absorbed more steadily in the gastrointestinal tract and its metabolism is non-insulin dependent. The ingestion of fructose minimally raises blood sugar levels, making it a suitable sweetener-replacement for type 2 diabetic diets. Eligibility of the participants included type 2 diabetes with a fasting blood sugar of 110-220 mg/dl. Forty eight type 2 diabetic subjects were randomly placed in two groups: one that took natural honey orally in fixed doses and another that

did not take honey or other drugs. Weight was monitored at the end of weeks two, four and six as well as before the study began and after it ended. Energy and nutrient intake as well as fasting blood sugar were measured before and after the study. Fasting blood sugar, Hemoglobin A1c, total-cholesterol, high-density lipoprotein cholesterol and low-density lipoprotein cholesterol were all measured amongst other biochemical markers that are not related to our study. The study performed was a randomized, controlled study that asked all participants to continue their usual diet throughout the duration of the study. Before the eight weeks, weight, fasting blood glucose and all other biochemical indices were comparable between the two groups. After the eight weeks, the honey group had significant reductions in body weight (a 1.8kg reduction with a deviation of +/-11.9kg), total cholesterol (decrease of 36.9mg/dl), LDL cholesterol (17.9mg/dl decrease) and fasting blood glucose (a 29mg/dl decrease), and a significant increase in HDL cholesterol (6.9mg/dl with a deviation of +/-15.1). The levels of Hemoglobin A1c increased unexpectedly in this group by 0.6mg/dl therefore, consuming honey by diabetic patients should be approached cautiously (Bahrami et al, 2009). In this study, consumption of honey was shown to have a significant and healthful effect on biochemical markers and weight loss, therefore as a potential therapy for type 2 diabetics.

In another study from Iran, researchers were able to find a link between consuming honey and a reduction of cardiovascular risk factors in healthy, overweight, and obese individuals. The participants were between the ages of 20 and 60 and were not taking any medication, on a special diet or exercise regimen. Subjects were either healthy, diabetic, or had hyperlipidemia. There were 40 participants in the experimental group and 20 in the control. The experimental group was given 70 grams of unprocessed honey dissolved in 250 ml of tap water daily. Participants in the control group were given 70 grams of sucrose in 250 ml of tap water daily. This went on for

a maximum of 30 days. Before the study commenced and every 30 days thereafter, subject's height, weight, body fat percentage (BF%), and body fat weight (BFW) were all measured. BMI was calculated using height and weight values. Blood samples were taken after an overnight fast to obtain total cholesterol, HDL-C, LDL-C, triacylglycerol, C-reactive protein, and fasting blood glucose (FBG). In subjects with normal values, the experimental group showed a significant reduction in BMI and FBG. In subjects with elevated lab values, in the experimental group, there showed a significant reduction in serum C-reactive protein and triacylglycerol. C-reactive protein is a blood serum protein that is a blood marker of inflammation. This serum protein is at the forefront of medical research currently and has been linked to the formation of atherothrombosus, therefore a reduction in this protein is significant. Honey had insignificant reductions in C-LDL, total cholesterol, triacylglycerol, CRP, and mild increases in C-HLD in the experimental group with normal lab values. In the experimental group with elevated values, there were insignificant reductions in body weight, body fat %, body fat weight, total cholesterol, and mild increases in C-HDL. Overall, this study proved on some level that introducing honey into the diet can have significant reducing power on cardiovascular risk factors in both healthy individuals and patients with diabetes and hyperlipidemia. Even though some lab values and anthropometric measurements showed statistically insignificant changes, in the clinical setting, these changes can have a great effect on the life of a patient. This study, like the previous one, was only done over a short period of time, and the researchers suspect that use of honey over a longer period of time could have a more significant effect (Aghasizadeh et al, 2008).

Method/Design

Three different samples of snicker doodle cookies were created, starting with a control recipe from The Joy of Cooking, referenced in appendix 1. The recipe called for 258 grams of

all-purpose flour, 9.5 grams of cream of tartar, 4.7 grams of baking soda, and 1.2 grams of salt. These were all combined in a large bowl where they were mixed together using a wire whisk. Researcher whisked these ingredients with 19 strokes from the outside of bowl to the center and then one complete stroke around the entire bowl. The next step is where the only variation occurred. In a separate large bowl, 129 grams of butter and 2 small eggs were combined with the varied amount of sugar or honey crystals. In the control recipe, 193.5 grams of sugar was used, in the 100% honey replacement, 193.5 grams of honey crystals were used, in the 75% honey replacement, 145.1 grams of honey crystals were used. These respective wet ingredients were beat with an electrical hand held mixer on power level 2 for 2 minutes and 9 seconds. Next, the dry ingredients were added to the large bowl containing the wet ingredients. These two were combined using a serving spoon with 50 strokes, creating a wet dough. Using a "cookie dropper", sized at 1/8 of a cup, we measured out dough balls. Researchers scooped out dough manually. This dough was dropped on two opposite sides into a small bowl containing a sugar and cinnamon combination consisting of 16.2 grams of sugar and 9.5 grams of cinnamon. Dough balls were manually rolled into a smooth rough shape for 2 seconds each. This was done to smooth dough and to spread cinnamon and sugar coating evenly. The dough balls were placed 2 ¾ inch apart on 16" x 14" baking sheet. They were cooked for 10 minutes at 350 ˚F, using top & bottom heating. Cookies were frozen in sealed Tupper wear containers until final subjective trial date. Thirty minutes before subjective testing, two cookies at a time were wrapped in 2 damp paper towels and micro-waved for 20 seconds at high heat.

We performed objective tests to determine the differences in wetability and spreadability of the three samples. To measure wettability, we tested how much water each cookie could absorb. Wettability is a measurement of how moist a product is. Products that will absorb more

water are ones that already have more moisture to begin with (McWilliams, 2008). We started by weighing a cookie from each sample group alone, then held it in 1 cup of water for 10 seconds using a finger tip, and then weighed each cookie again immediately after. To measure spreadability, we randomly chose 1 cookie from each portion controlled sample group and traced it using a pencil onto a piece of paper. Since our portions were controlled, the dough balls started at exactly the same size, therefore the variance between sizes of cooked cookies will prove its ability to spread after being baked. This measurement was a slight variation on the line-spread test. We then measured the diameter both horizontally and vertically using a ruler. We averaged these two measurements. To find the area of the cookie, we divided the averaged diameter by two to get the radius and plugged it into the equation for area = πr^2.

For testing acceptability, each cookie was cut into 4 even pieces using a chef's knife. Pieces were placed in small Dixie cups and served on paper plate designating each sample with a randomized number. Participants were given $1/4^{th}$ cookie sample of each of the three types. The control was labeled "481", 100% honey replaced was labeled "216", and 75% honey replaced was labeled "729". Participants were given three different half sheets of paper with score cards on them. The questions aimed to evaluate three different dimensions of the cookies, hardness, mouth-feel, and overall acceptability. Hardness was a quality tested to examine moisture quality before tasting. A score of 1 indicates the "very soft", a score of 5 indicates "soft" and a score of 9 indicates most hard or "very crumbly". Mouth-feel was chosen to evaluate overall tenderness of the cookie. A score of 1 indicates "very hard", a score of 5 means "tender", and a score of 9 is "very tender". Then overall acceptability was the last test performed by participants and this measured if honey could be a replacement for sugar. A score of 1 indicates the cookie is "not acceptable" and a score of 9 meant "very acceptable".

Results & Discussion

For the objective tests, wettability and spreadability were measured using each sample. The results are explained as followed and charted in appendix 2. The starting weight for the control cookie was 17.0 grams and the ending weight was 40.4 grams, resulting in an increased water weight of 23.4 grams. For 100% honey replaced cookies, the starting weight was 20.2 grams and the ending weight was 43.3 grams, meaning there was a 23.1 gram increase after being submerged in water. Lastly, the 75% honey replaced cookies started at 18.5 grams and ended at 35.0 grams; this was a 16.5 gram increase. According to this test, our control cookies had the greatest amount of wettability. The measurements of the spreadability tests were given in terms of area of the cookies, the results of which will be explained as well as charted in appendix 3. The control cookie measured had an average diameter of 7.5 cm and an area of 44.158 cm. The 100% honey replaced cookie had an average diameter of 6.7 cm and an area of 35.2 cm. The 75% honey replaced cookie had an average diameter of 6.7 cm and an area of 35.2 cm.

For the subjective test, participants were asked to rate the three samples based on hardness of cookie, mouth-feel of cookie, and overall acceptability. The raw data for the subjective tests can be found in the appendix; control is in appendix 4, 100% honey replaced is in appendix 5, and 75% honey replaced is in appendix 6. The scorecard used in is located in appendix 7. Graphs displaying a graphed form of these averages are located as follows: Appendix 9 shows averages for the control, appendix 10 shows the averages for the 100% honey replaced cookies, and Appendix 11 shows averages for 75% honey replaced cookies. For the hardness test, a soft cookie is ideal; therefore we deemed the lower the score, the more ideal. The control was given the highest scores and therefore rated the hardest cookie—with an average score of 7.04. This meant participants felt the cookie was the most crumbly of the three samples.

The 100% honey replaced cookies scored the second hardest, with an average score of 6.08. The 75% honey replaced cookies were scored as the most soft, there average score was 2.6. For mouth-feel, a higher score meant more tender and therefore more ideal. The average score for tenderness of the control sample was 3.88. This was the lowest of all three scores. The 100% honey replaced cookies were rated on average slightly higher, scoring at 4.68. The 75% honey replaced cookies scored the highest in tenderness. Their average score was 7.40, meaning participants felt they were most tender. Lastly, participants were asked about overall acceptability of the products. The control cookies were rated the lowest, with an average acceptability score of 6.52. The 100% honey replacement was rated on average at 6.56. And finally, the 75% honey replacement cookies had an average rating of 6.62. These scores had the least amount of variance from one another, in comparison to the scores for "hardness" and "mouth-feel".

The wettability test is done to predict the results of a subjective test that determines moisture of a baked product (McWilliams, 2008). In this project's case, the objective test was incorrect in predicting which samples the subjects would find most moist. The objective tests found the control to have the highest wettability, followed by the 100% honey replaced, and lastly the 75% honey replaced. Participants in the subjective test found the opposite to be true. They found the 75% honey replaced cookies to be most soft compared to 100% honey replaced—with a difference of 4.2 in their scores. The difference between the 100% honey replaced cookies and the control cookies was much less significant, with a 0.96 difference in their scores. When scoring tenderness or mouth-feel, the participant's scores were in a similar pattern as that of their hardness scores. They scored the 75% replacement cookies to be significantly more tender, than 100% honey replaced cookies, which were then still slightly more

tender than the control cookies. These discrepancies can be explained by multiple reasons. The first of which is that the control cookies and the 100% honey replaced cookies used in the subjective tests were frozen for the longest amount of time in comparison to the 75% honey replaced cookies. Although the defrosting method was controlled, this could still be proven significant by our results. The second potential reason for the disconnect between the subjective and objective tests was that during our objective tests we only tested one cookie from each of the three sample, as opposed to averaging multiple tests to find a more accurate number. The last potential explanation for the discrepancy is our use of the standardized portioning tool for only the 75% honey replaced cookies during the subjective tests, and using this tool for all samples during the objective tests. This could make a difference in the shape of the cookies which could therefore effect how they cooked as well as how well they retained moisture in storage. Because sugar crystals sometimes form during storage, this causes cookies to become stale and harder. The control and 100% honey replaced cookies were stored for the longest period of time, which could also explain why they scored higher on the hardness scale according to the participants during the subjective tests. In baking, because of honey's higher percentage of fructose, it is able to absorb more moisture from the atmosphere ("Baking ingredients and," 2005). An increase in moisture will also increase tenderness. This could also explain the results of subjective tests for mouth-feel, where participants felt the two products containing honey were most tender. In the objective test determining spread of the samples, the increased area of the 100% honey replaced cookie, can be attributed to the higher hygroscopicity of honey over sucrose. Although the 75% honey replaced cookies were still comprised of the hygroscopic honey, they contained $3/4^{th}$ the amount of sugar than both the control (that contained only sucrose) and the 100% honey replaced cookies and therefore their ability to absorb water and spread was reduced. This objective test

could also have potential error because we only performed the test on one cookie from each sample group, the more accurate approach would have been to do the test on multiple cookies in each group and average their results. In general, objective tests and subjective tests can have varying results because of taste preferences of participants. Objective trials are only meant to help predict subjective results, which is why we think the results of the subjective tests are more significant, despite our errors.

Conclusion

Through the results of our subjective tests, our hypothesis is supported. Less honey can be used to replace table sugar, or sucrose. If more people worldwide chose to replace sucrose with lesser amounts of honey when baking, this may potentially result in less weight gain and therefore less obesity prevalence. Because the correlations between weight gain, obesity, cardiovascular disease, and diabetes are so strong, reducing weight gain can lead to a lower risk of cardiovascular disease and diabetes. Although having an unhealthy diet is only one factor in the risk of these diseases, tackling one at a time can still have a significant impact. In our subjective trials, the participants higher scoring of the 75% honey replaced cookies supports our belief that people can lead healthier lives by using honey in lesser amounts to replace sucrose in baked products. They unknowingly accepted the cookies that contained fewer calories and less sugar. We believe that such simple steps in the kitchen like honey replacement of sucrose may have a significant impact on the world's obesity epidemic.