Satiety Among Five Common Foods when Compared to White Bread

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Janeza Bridges

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Nutrition 302L - Advanced Nutrition Laboratory

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Jeff Moore

San Diego State University

School of Exercise and Nutritional Sciences

Abstract

To determine if there is a difference in satiety among five common food items, a mean satiety score was determined for each food item. By knowing the satiety difference among various food items, we can make rational decisions, which in turn, may lead to a decrease in overconsumption. Overconsumption has been shown to play a major role in obesity. Students at San Diego State University participated in a study where satiety levels of food were collected over two testing sessions. Results showed a difference among the five food items, however due to possible limitations and errors, a statistically significant difference was not able to be claimed. Further research is needed with a tighter restriction on testing methods and a larger sample size.

Keywords: *satiety, satiation, obesity, satiety levels*

Introduction

Satiety is the feeling of fullness after a meal. The more satiating a food is, the longer the feeling of fullness. One problem with food having low satiety levels is that it may lead to food overconsumption, which in the long run, may lead to obesity (Blundell et al. 2008). Many diseases stem from obesity. This includes, but not limited to, cancer, diabetes, hypertension, stroke, and osteoarthritis (Khaodhiar et al. 1999). By knowing the satiety index of common foods, people can make rational decisions when it comes to their food choices and lessen the chances of food overconsumption.

The key focus of this study is whether five common food items, acting as the independent variable (IV), has a significant impact on satiety scores, acting as the dependent variable (DV). Having a significant difference between scores will show that manipulation of an individual's choice of food influences their level of satiety. Foods included in the study consisted of white bread, croissants, peanuts, bananas, and hard-boiled eggs. Students were instructed to arrive to class fasted and record satiety scores over a two-hour period with one of the five food items randomly assigned. Three weeks later, students were instructed to do the same with white bread, which acted as the control group. Past studies have been done using satiety scores to interpret differences among foods. The study done at San Diego State University (SDSU) roughly mimics the study conducted by *Holt et al.* (1995) The study concluded that different foods varied greatly in levels of satiety, therefore, it is hypothesized that there will be a significant difference between the five common food items.

Methods

Materials:

Food samples, measuring equipment, and glucose monitoring supplies were needed to complete this experiment. A *Mettler Toledo ME54E* scale was used to measure samples. One scale was shared among four to five students. Other materials needed were *Nova Max Glucose Test Strips*, *Nova Max Plus Glucose Monitor*, *CareTouch Lancing Device with Ejector*, alcohol wipes, gauze pads, and paper towels (*see table I*).

Food items for day one included *Almark* hard-boiled eggs (165 grams), *Chiquita* bananas (281 grams), *Wonder Bread* white bread (102 grams), *First Street* croissants (77.5 grams), *First Street* peanuts (42 grams), and a cup of *Arrowhead* water (8 ounces) (see Table II). Day two of testing consisted of *Wonder Bread* white bread and *First Street* peanuts for those with special dietary needs, as well as a cup of *Arrowhead* water (8 ounces) (see Table III).

Table I: Materials needed for each participant with amount needed per testing day. *Mettler Toledo ME54E* scale was shared among students.

Item	Amount per Student
Mettler Toledo ME54E Scale	1 (Shared)
Nova Max Glucose Test Strips	14
Nova Max Plus Glucose Monitor	1
CareTouch Lancing Device with Ejector	1
Alcohol wipes	7
Gauze Pads	7
Paper Towels	2

Table II: Foods to be used with brand name and amount in grams equal to 250 calories and ounces for water.

Food	Brand	Amount (Grams)
Hard-Boiled Egg	Almark	165 grams
Banana	Chiquita	281 grams
White Bread	Wonder Bread	102 grams
Croissant	First Street	77.5 grams
Peanuts	First Street	42 grams
Cup of Water	Arrowhead	8 ounces

Participants:

Demographics. There was a total of six males and sixty-eight females who participated in the study, for a total of 74 participants. All results given as mean (standard deviation): 24.22 years (±6.42), weight 63.75kg (±9.82), height 1.64m (±.08), and BMI 23.61 kg/m^2 (±3.3) (*see Table IV*).

Inclusion / Exclusion Criteria. Inclusion criteria for the study consisted of students enrolled in SDSU's *Nutrition 302L* (*Advanced Nutrition Lab*) course with exclusion criteria being any person(s) with an eating disorder or history of an eating disorder. Having an eating disorder may skew results due to the person(s) view on food.

Table IV: Average age, weight, height, BMI, and standard deviation of participants.

	Age (years)	Weight (kg)	Height (m)	BMI (kg/m^2)
Mean	24.22	63.75	1.64	23.61
Standard Deviation	6.42	9.82	.08	3.3

Design:

Testing - Day One. Students were asked to fast for at least eight hours prior to the testing date. Day one of testing began at nine-thirty a.m. on April 2, 2021. Students were randomly assigned one of the five food items: peanuts, hard-boiled eggs, bananas, white bread, croissants. Those with special dietary needs were automatically given peanuts. Once given, each food item was to be calculated and weighed (in grams) on a scale to equal 250 calories and cups of water were placed on their tables. Students were also given a blank *Satiety Data Sheet* to collect results (*see Appendix A*). Before consumption (at *0* minutes), students were asked to take two glucose level readings and a satiety score from *1* to *7* with *1* being *extremely hungry* and *7* being *extremely full* (*see Glucose Reading Instructions*). Δ satiety score was not taken for the initial reading.

Once two base readings for glucose (mg/dL) are taken, a timer is set for 15 minutes, then food is immediately consumed. Glucose levels, satiety scores, and Δ satiety scores were then taken every 15 minutes for a duration of 120 minutes. Glucose levels were not taken for minutes 75 and 105, satiety scores and Δ satiety scores were taken. Students were allowed water for the entire duration of the study. Once 120 minutes passed, students could leave and were asked to return in three weeks.

Testing - Day Two. Students were asked to follow the same guidelines for day one which included fasting for about eight hours prior to arriving at the testing site. The same protocol was given as day one except instead of randomly being assigned one of the five foods, students were given either white bread (those with no dietary restrictions) or peanuts (those with dietary restrictions). Once data collection for the 120 minutes was complete, students could leave which ended the data collection portion of the study.

Glucose Reading Instructions. Students were to either test each other's glucose levels or individually take glucose levels. A paper towel was placed on the table to place glucose lancing devices, test strips, monitors, gauze pads, and alcohol wipes on. One finger (middle or ring finger recommended) is to be wiped down with an alcohol wipe. The lancing device head was unscrewed to allow for a needle to be placed. The cap of the needle was then twisted off and the lancing device head was screwed back to its original state. Adjust the depth of penetration between the *6* and *7* reading. Pull base back until it clicks. Aim tip to the area of the finger you want blood drawn, then press the button on the side to release. Once released, blood should slightly come out. If not enough is available, squeeze your finger to draw out more blood. Once enough has been accumulated, place a glucose test strip on the glucose monitor. Place the edge of the glucose test strip to the blood from your finger and wait for the glucose monitor to show blood droplets. Once reading is finished, a number should show up on the screen. Record the results onto the *Satiety Data Sheet*.

Calculations:

AUC and IAUC. To calculate IAUC, AUC must first be determined. To do this, the duration of time (15 minutes) will be multiplied by the average value for the satiety level of t=0 and t=15 for each 15-minute interval in a 120-minute period. This will give seven trapezoidal areas that when added together will give the AUC. To determine IAUC, a horizontal line is established at the base satiety level for t=0. This area below the line is subtracted from the AUC, giving us IAUC or area above the line and under the curve (*see Table V*).

Table V:

Equations
AUC = $X*(Y^{1+}Y^{2})/2 + X*(Y^{2+}Y^{3})/2 + X*(Y^{3+}Y^{4})/2…$
IAUC = AUC - (Y^{1}*total time)
Satiety Score = (AUC Test Food / AUC White Bread) * 100

Mean and Standard Deviation. The average satiety level for each item taken in 15-minute intervals allows the AUC and IAUC to be determined. Once calculated for, take the sum of all satiety scores for one food, then divide by the number of subjects. Calculate for each food item. Standard deviation for each food item will be calculated using *Microsoft Excel*. Standard deviation is calculated as follows: designate an empty cell on the sheet and click → locate *Insert* on top bar → click *Function* → *STDEV.P* → highlight score values → press *Enter/Return* key. Repeat for each food item. Calculation will also be used to calculate participant data.

ANOVA One-Way. The One-way Analysis of Variance (ANOVA) test provides us an analysis on whether the means of at least three groups are different. In the case of this experiment, the means of five common food items will be tested - Peanuts, white bread, hard-boiled eggs, croissants, and bananas. Required for a one-way ANOVA test are one categorial factor for the independent variable (IV) and a continuous variable for the dependent variable. The independent variable assigned to this study will be the five food items with the dependent variable (DV) being the satiety score. The ANOVA one-way test will be performed on *Microsoft Excel*. Each food item will be assigned one column. In Microsoft Excel the steps are as follows: Click *Data Analysis* → *ANOVA: Single Factor* → Under *Input*, select ranges for all columns of data → *In Grouped By*, choose *Columns* → Check *Labels* → Adjust *Alpha* value to *0.05* → Click

OK. Having a value less than our critical level of 0.05 signifies rejecting the null hypothesis with the null hypothesis being that all satiety scores are equal amongst food items.

Results

Participant Descriptive Statistics. There was a total of six males and sixty-eight females who participated in the study, for a total of 74 participants. All results given as mean (standard deviation): age 24.22 years (±6.42), height 1.64m (±.08), weight 63.75kg (±9.82), and BMI 23.61 kg/m^2 (±3.33) (*see Table VI*).

Table VI: Descriptive statistics of participant's age, height (m), weight (kg), BMI, mean, and standard deviation.

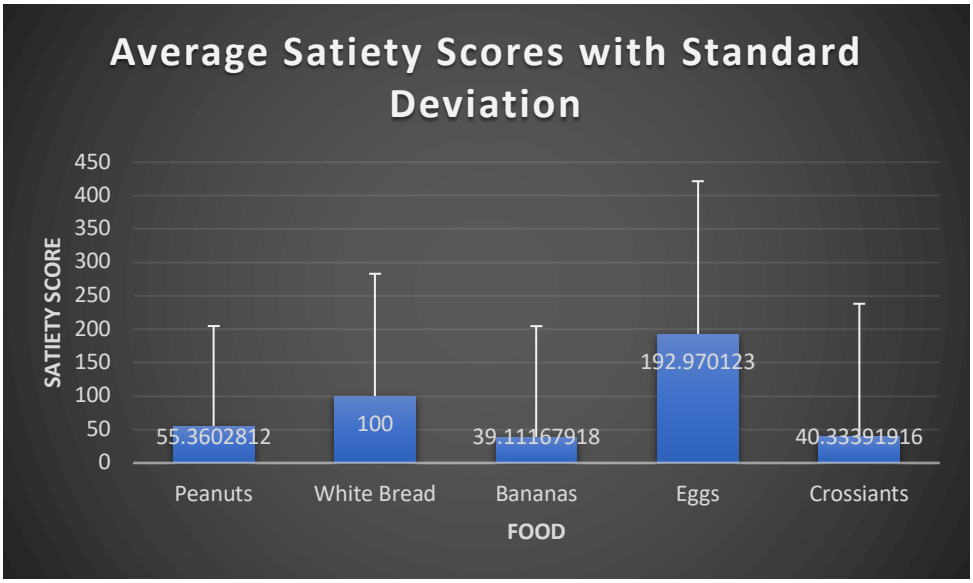
	N	Mean	Standard Deviation
Age	64	24.22	6.42
Height (m)	63	1.64	.08
Weight (kg)	64	63.75	9.82
BMI (kg/m^2)	63	23.61	3.33

Satiety Scores - Mean and Standard Deviation. IAUC shown as average (SD): peanuts 55.36 (±149.48), white bread 100 (±183.08), bananas 39.11 (±165.58), eggs 192.97 (±228.57), and croissants 40.33 (±197.85) (*see Table VII* and *Figure I).*

Table VII: Average satiety scores and standard deviation of the five common foods after IAUC was calculated.

Food Item	Satiety Score	Standard Deviation
Peanuts	55.36	149.48
White Bread	100	183.08
Bananas	39.11	165.58
Hard-Boiled Eggs	192.97	228.57
Croissants	40.33	197.85

Figure I: Average satiety scores of peanuts, white bread, bananas, eggs, and croissants with standard deviation. SD values: peanuts: 149.48, white bread: 183.08, bananas: 39.11, eggs: 228.57, croissants: 197.85.



ANOVA One-Way. After data was input onto *Microsoft Excel*, the ANOVA (one-way) statistical analysis delivered a p-value of 0.29, which is significantly greater than our critical level of p=0.05. The p-value, 0.29, being greater than our critical level, p=0.05, results in failure to reject the null hypothesis.

Discussion

Statistical Analysis

Satiety scores differed among each of the five food items, as shown in *Figure I*, with boiled eggs showing the highest satiety score (192.97) and bananas being the lowest (39.11). Compared to white bread, which acted as our control group, the only food item to surpass the level of satiety was shown to be boiled eggs, with peanuts (55.36), bananas (39.11), and croissants (40.33) showing lower levels of satiety. To reach the same level of satiety as white

bread there needed to be about twice the number of peanuts and about two and a half the number of bananas and croissants. About half the number of eggs would be needed to reach the same level of satiety as white bread. Based on these scores, we can see that there is a difference among these five common foods, however, the ANOVA one-way test shows otherwise. The ANOVA one-way statistical analysis delivers a p-value of .29, which is significantly greater than our critical level of p=0.05, therefore, we fail to reject our null hypothesis. Meaning we cannot claim there is a statistically significant difference between eggs, peanuts, croissants, bananas, or white bread.

Average satiety scores and standard deviation (SD), shown in *Table VII*, show high variability. Approximately, white bread showed a SD of double the mean, peanuts three times, bananas four times, croissants five times, and hard-boiled eggs having close to a one-to-one ratio, which shows we have a large spread from the mean for each food. Ideally, when conducting a 95% confidence interval, you would consider a 2 standard deviation interval from the mean to have 95% confidence that the true value lies within the interval. In this case, the interval is so large that we are unable to deduce distinguishable analysis. In the future, mitigating this issue would require a larger sample size and improved data collection.

Limitations

Research statistics are used to draw conclusions about a population based on the information collected in a sample from that population. With high variability amongst the data, errors and limitations may be prevalent. Some limitations may include too small of a sample size, insufficient calorie requirement (250 calories), lack of participant diversity, and dietary bias. Errors may have included random errors such as equipment malfunction, systematic errors based on methods, or individual errors while measuring or calculating.

As shown in our results, standard deviation of mean satiety score varied greatly among each sample. The sample mean is always approximately the same as the population mean. With a small sample size of 74 participants, the standard deviation of the mean increases, whereas having a larger sample size would result in a decrease. In other words, having a small sample size reduces the power of the study and increases the margin of error which was shown when looking at *Figure I*.

To be considered a participant in the study, participants are required to be enrolled in the *Nutrition 302L* (*Advanced Nutrition Lab*). Being a nutrition course, a lack of diversity and dietary bias may be present. Participants with an eating disorder or having a past of an eating disorder were excluded from the study, however, no exclusions were made with participants' diets or number of calories eaten per day, which may create dietary bias. A study conducted by *Finkelstein* shows that a participant's appetite is increased when health is a driver (2010). With this in consideration, it is possible that having only nutrition students as participants may lead to dietary bias and therefore may not be a good representation of populations who are not as health conscious/knowledgeable. Having 92% of participants being female may also impact results. Men and women were required to consume the same number of calories (250 calories); however, studies have shown that there is a difference in hunger and satiety among men and women (Bédard et al. 2015). No difference in calories of food between men and women may result in an insufficient number of calories required to reach a level of satiety.

Errors

Highly variable data may indicate errors were present during the study. These include random, systematic, and personal errors. Random errors may include some of the equipment used such as food sample scales and glucose reading monitors. Systematic errors may have been

a result of an inaccuracy or mistake within methods. Personal errors or blunders include measurement errors or incorrect value input. With not having been trained beforehand, personal and systematic errors may be likely to have played a role in variability for the data.

Nutrition and Physiology

The common food items categorized by macronutrient group are as follows: peanuts (fats), croissants (carbohydrates), hard-boiled eggs (protein), white bread (carbohydrate), and banana (carbohydrate). When put in order of satiation (highest to least), foods are as follows: hard-boiled eggs, bread, peanuts, croissants, bananas. Among the three macronutrients, fats (lipids), proteins, and carbohydrates, proteins are known to be the most satiating with carbohydrates being second (Chambers et al. 2015). *Figure I* reflect proteins as being more satiating, however, mean satiety levels for croissants, peanuts, and bananas do not follow this statement. Reasons may be the type of carbohydrate, ingredients used (ingredients used to produce croissants versus white bread), or amount of food given. Not all foods have equal serving sizes. Having all foods total 250 calories results in some foods being more than one serving while others may be less or equal to one serving. An example of this may be with white bread and croissants. One serving of white bread is two slices (46g), whereas the serving size of croissants is one (113g). For this study, 250 calories for these two foods were white bread (102g) and croissants (77.5g). Knowing one serving and knowing the amount (in grams) to reach 250 calories, we can see that to reach 250 calories, 2.22 servings of white bread and 1.46 servings of croissants. This may explain why the satiety level of white bread shows to be higher than that of croissants. Further research is needed to produce more statistically significant results.

Conclusion

Past studies have shown that a difference in levels of satiety exists among different foods. This study focuses on the satiety among five common food items and how they compared to white bread. The food items consisted of peanuts, bananas, white bread, hard-boiled eggs, and croissants. It was hypothesized that there will be a difference in satiety among the five common foods. Results show a difference among each food item with only hard-boiled eggs surpassing white bread in satiety, however statistical analysis shows that there is no statistically significant difference. Having no statistical significance may be due to limitations such as poor sample selection/size, dietary bias, or errors within the study. Knowing the effects of satiety among common foods gives us a chance to make more rational decisions on our food choices and lessen the chances of overconsumption, especially with obesity being a large risk factor for many diseases.

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Appendices:

Appendix A: Satiety Data Sheet to be filled out by students. Blood glucose (mg/dL) levels were taken twice every 15 minutes for 120 minutes with minutes 75 and 105 as an exception.

Subject:	DOB:	Height (cm):	Weight (kg):	BMI:	Sex:	Ethnicity:

Food Item:		Date:			Time:		Hours Fasted:		
Time (min)	0	15	30	45	60	75	90	105	120
Satiety Score									
Δ Satiety Score									
Blood Glucose (mg/dL)									

Food Item:		Date:			Time:		Hours Fasted:		
Time (min)	0	15	30	45	60	75	90	105	120
Satiety Score									
Δ Satiety Score									
Blood Glucose (mg/dL)									

Food Item:		Date:			Time:		Hours Fasted:		
Time (min)	0	15	30	45	60	75	90	105	120
Satiety Score									
Δ Satiety Score									
Blood Glucose (mg/dL)									

extremely hungry	hungry	semi hungry	no particular feeling	semi satisfied	satisfied	extremely full
1	2	3	4	5	6	7