Quantifying the "Golden Ratio" of Hyper-Palatable Foods: What Makes Junk Food So Addictive?

Madeleine Schabes

Advisor: Dr. An-Phong Le

Department of Chemistry, Biochemistry, and Physics

Florida Southern College

May 2022

Abstract

The rising popularity of hyper-palatable foods is motivating research on what makes a food addictive. The current research focuses on neurological and psychological explanations, not on the foods' physical makeup. It is suggested that food companies strategize the ratio of salts, sugars, and fats to overcome a person's natural eating regulation, or sensory-specific satiety (SSS.) This strategy is referred to as the "golden ratio" or "bliss point" but has never been quantified. The study will compare popular and unpopular potato chips as determined by purchasing trends and rankings. For this investigation, the salt, sugar, and fat content was measured through analyzing chloride, dextrose, sucrose, fructose, lactose, and solid fat content. Subsequent statistical analyses will find if different ratios exist between popular and unpopular potato chips. If a common ratio is found, it could aid in ingredient reduction without affecting palatability. This can be a major cost-saving measure for the food industry, and it could make foods healthier for people with conditions such as diabetes and hypertension.

Introduction

In 2013, investigative journalist Michael Moss published his book *Salt Sugar Fat: How the Food Giants Hooked Us,* discussing business strategies of the food industry. One claim was that food companies strategically balance levels of salt, sugar, and fat in processed foods to make customers over consume them.[1] This ratio is known as the "Golden Ratio." The increasing popularity and fascination with these foods has garnered them an official name: hyper-palatable foods. Their addictive nature prompted many studies on how the brain reacts to certain flavor stimuli or how they contribute to the obesity epidemic.[2–5]

Receiving knowledge of a universal, optimized recipe could mean tastier, healthier, and cheaper foods. It was already found foods with elevated levels of salt, sugar, or fat tricks the brain's natural satiation strategy.[6] Sensory-specific satiety (SSS) is a physiological response to an excess of one flavor, decreasing an individual's craving and preventing them from overeating. Balancing more than one flavor, like sweet and salty, can elicit a weaker SSS response, causing consumers to overeat. To make healthier and cheaper foods, the "bliss point" must be recognized as a "bliss range." If consumer's satisfaction vs. salt/sugar/fat concentration was graphed on a curve, the peak corresponding to most satisfaction is not a singular point, but a range of values.[1] If the lower end of the range was used, the slight reduction in salt/sugar/fat could be beneficial to people with health risks such as diabetes and hypertension.

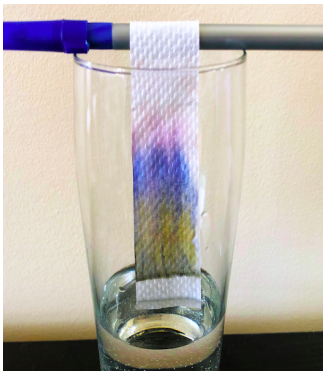
The only scientific evidence Moss provided for his claim were taste tests and subsequent statistical analysis. While the taste tests suggested a food could be optimized, other factors were considered such as texture, packaging, and visual appearance.[1] Therefore, a study needed to be conducted on considering salt, sugar, and fat levels alone. Scientifically, there are more specific classifications of molecules than just "salt, sugar, and fat." Measuring salt could just include measuring table salt content, or NaCl. To be more encompassing, this study will analyze all chloride (Cl^-) content, which includes KCl and $CaCl_2$ as well. Similar to how there are more salts than just table salt, there are more sugars than just table sugar. Sugars are more accurately known as simple carbohydrates, which can include molecules lesser known

as sugars, such as lactose.[7] To keep this study simpler, only the most common sugars will be examined: sucrose, dextrose, fructose, and lactose. Dextrose is similar to glucose; glucose includes both L-glucose and D-glucose, whereas dextrose is just the D-form.[8] For fat, the definition can vary widely depending on country or by constituents. The FDA in the US determined "total fat" is the measurement of saturated fats, unsaturated fats, and *trans* fats. Other places such as Brazil and Hong Kong use "crude fat" on their nutrition labels, which is defined as the sum of all fat-soluble compounds.[9] This is larger than total fat because it includes steroids, fat-soluble vitamins, carotene pigments, and chlorophylls.[10] Crude fat is first isolated from food matrices using a solvent extraction such as the Soxhlet or Bligh-Dyer methods. The crude fat can be separated into its constituents later through gas chromatography-mass spectrometry (GC-MS.)[9] Only crude fat was determined in this study due to time constraints.

These macronutrients needed to be quantified exactly due to an absence of research. Nutrition labels supply unreliable numbers that are not specific enough for finding differences between hyper-palatable (HP) and non hyper-palatable (NHP) foods. For example, sugar and total fat can be labeled as 0g if there is less than 0.5g per serving. Similarly, salt is labeled as 0mg if there is less than 5mg per serving.[11] The U.S. Food and Drug Administration (FDA) also allows for a margin of error for up to 20% on the stated value for nutrients.[12] Since nutrition labels provide an estimate and not exact values, more advanced methods of measurement are required.

In a study by Zaky et al., chromatographic separation and detection of chloride, sugars, organic acids, and alcohols was achieved using an HPLC equipped with a cationic exchange column and a refractive index detector.[13] HPLC stands for High Performance Liquid Chromatography, a process carried out by a machine that separates molecules based on size, charge, polarity, and more. An elementary example of chromatography is separating marker ink into its separate dyes when soaking paper in water (**Figure 1**.) As the water travels upwards, lighter dye molecules travel longer and heavier dye molecules resist the current, depositing earlier. There are three basic parts to a chromatography experiment: the analyte, the stationary phase, and the mobile phase. The analyte is the sample, like the marker in **Figure 1**. The stationary phase is what is packed into the column and separates the molecules. In the marker experiment, this is the paper. The mobile phase is the solvent that carries the analyte through the column, which is the water in **Figure 1**.

Figure 1: Chromatographic separation of the dyes in marker ink[14]



In the case of a cationic exchange column, specifically a Hi-Plex H column in Zaky et al., the molecules are separated based on charge, where the column is negatively charged and positively charged molecules will "stick" to the column (**Figure 2**.) The Hi-Plex H column is packed with sulfonated polystyrene divinylbenzene media, which is made of polystyrene/divinylbenzene (PS/DVB)

microbeads with sulfonic acid (-SO_3H) added to their surfaces (**Figure 3**.)[15]

Figure 2: How ions are separated in a cationic exchange column[16]

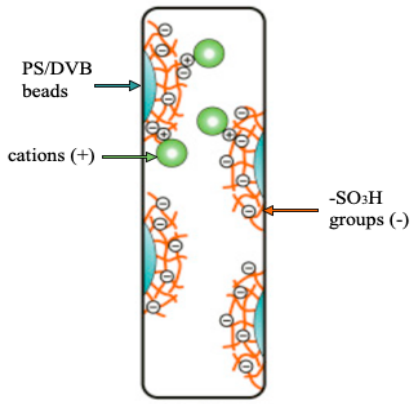
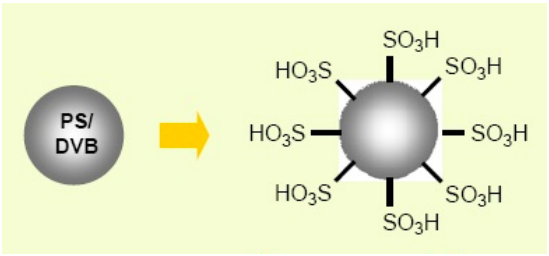
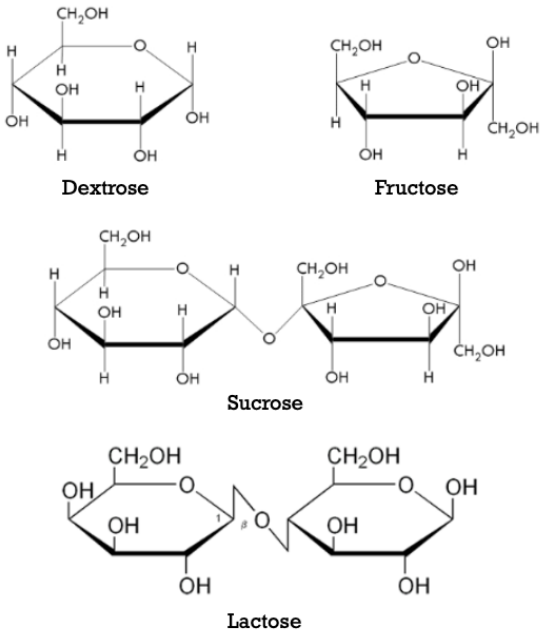


Figure 3: Sulfonated PS/DVB microbeads found in the Hi-Plex H column[15]



These types of columns are commonly used for the separation of sugars in HPLC due to the partial negative hydroxyl groups found on all their structures (**Figure 4**.)[15] The chloride ion in salt is the most negatively charged, so it will elute first as it is the most repelled by the microbeads. Of the sugars, sucrose has the most hydroxyl groups and is eluted second. Lactose is eluted third with the second most hydroxyl groups. Dextrose and fructose have the same amount of hydroxyl groups, but fructose has a bulkier structure with two -CH_2OH groups instead of one. This gives fructose a longer retention time as it lags in the column from a larger size.

Figure 4: Chemical structures of dextrose, fructose, sucrose (dextrose and fructose units,) and lactose (galactose and glucose units)[17,18]



The other component to note in the HPLC setup is the refractive index (RI) detector. Other detectors such as fluorescence and UV-V cannot be used without an extra derivatization step, since simple carbohydrates do not contain chromophores and fluorophores. The use of an RI detector prevents the extra derivatization step. The detector operates based on the difference between refractive index between the mobile phase and sample. RI can be impacted by temperature. Examples of this include the rippling effect as hot water mixes with cold water, or seeing the waves of heat emanate from a car hood. Therefore, a column oven is utilized to keep temperature constant and the baseline stable.[19]

To isolate fat from food samples, most traditional extraction methods take multiple hours to complete. The most widely known, the Soxhlet extraction, takes 16-24 hours.[9] There is also the issue of large

sample-to-solvent ratios of up to 1:20 with the Bligh-Dyer or Folch methods. Microwave-assisted extraction (MAE) provides both a short preparation time with less solvent waste. Studies have shown the new method yields a similar fat extract both qualitatively and quantitatively, high repeatability, and similar efficiency to the Bligh-Dyer and Folch methods.[20,21]

MAE extracts crude fat by using a nonpolar solvent, specifically petroleum ether. The microwave heats the solvent in contact with the sample, allowing the compound of interest to dissolve into the solvent. In this case, all nonpolar lipids will be extracted, while polar lipids such as free fatty acids and phospholipids are not. All fat extraction methods have a drying agent added before extraction due to the concern of water, a polar solvent being present and co-extracting polar lipids.[21]

Once the data is gathered on the macronutrient levels, statistical analysis is performed to unveil any correlations. A two-way multivariate analysis of variance (MANOVA) tests for whether the independent variables (IV) are different based on the dependent variables (DV.)[22] In this case, the independent variables would be food type (HP and NHP) and the dependent variables would be the concentrations of the different macronutrients. A MANOVA will analyze if HP and NHP are significantly different based on their macronutrient levels through a Wilks' Lambda Test. Lambda measures the variance in DV that is unexplained by differences between IV. A value of zero is ideal because it means there is no unexplained variance, meaning the IV classifications define the variance amongst DV well.[22]

For the scope of this study, potato chips were chosen as the food of interest. Both HP and NHP chip flavors were chosen based on online rankings, polls, and purchase trends.[23–28] It was assumed trending chips were more HP and unpopular chips were NHP. Seven HP chips were chosen (Nacho Cheese Doritos®, Cool Ranch Doritos®, Cheetos®, Cheddar and Sour Cream Ruffles®, Classic Lay's®, Salt and Vinegar Lay's®, and Sour Cream and Onion Lay's®) and two NHP chips were chosen (Harvest Cheddar Sun Chips and Munchos®).

Methods

Quantifying Chloride, Dextrose, Fructose, Glucose, Lactose, and Sucrose

Samples were prepared by weighing 4g of finely crushed chips into a 50mL centrifuge tube. 40mL of 85ºC DI water was added to each tube and samples were vortexed for 5 minutes. Samples were incubated in a 85ºC water bath and vortexed for an additional minute. The liquid was filtered with a Buchner funnel and the filtrate was collected. The filtrate was passed through 0.45µm syringe filters and 80µL was added to an HPLC vial. An additional 1mL of DI water was added to the vial.[13]

Chromatographic separation was performed using a Hi-Plex H column (7.7 x 300mm, 8µm)(Agilent Technologies, Inc.) and 0.0025M H_2SO_4 as the mobile phase. An RI detector was equipped with a column oven and set to 35ºC. All compounds of interest were eluted within 20 minutes at a flow rate of 0.4 mL/min and an injection volume of 10µL.[13]

Calibration curves were constructed for each analyte of interest: chloride, dextrose, fructose, glucose, lactose, and sucrose. For chloride, NaCl solutions in water were made at 0.02 g/L, 0.05 g/L, 0.1 g/L, 0.15 g/L, and 0.2 g/L. For all sugars, solutions in water were made at 0.01 g/L, 0.02 g/L, 0.05 g/L, 0.1 g/L, 0.2 g/L, and 0.5 g/L. The area under the curve was recorded

in μV*sec. All final curves had R^2 values above 0.995.

Quantifying Crude Fat

Monowave samples were prepared by adding 0.1667g crushed potato chips, 0.333g anhydrous Na_2SO_4, and 5mL 2:1 petroleum ether:acetone to a quartz extraction vessel equipped with a stir bar. The parameters were set to the following: extraction temperature 90ºC, ramp duration 10 minutes, and extraction duration 20 minutes. Once the run was finished, the sample was filtered into a pre-weighed filter flask. Any remaining solvent was evaporated at the lowest temperature setting on a hot plate. Final crude fat was determined gravimetrically.[21]

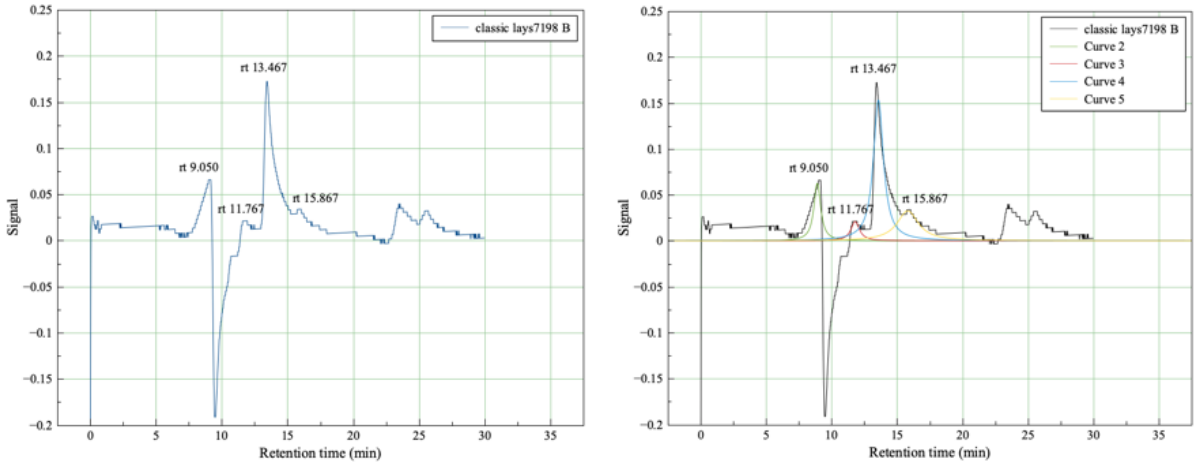
Results and Discussion

Analysis of HPLC Data

Before any potato chips could be run, calibration curves were constructed to relate the signal to real concentrations (see Appendix, **Figures 7-11.)** All curves had high correlation, with R^2 values ranging from 0.9991-0.9998. Average retention times were also extrapolated from the runs needed to make the curves (see Appendix, **Table 2.)** While the retention times varied slightly from Zaky et al., all analytes of interest eluted in the same order as theirs did: chloride, sucrose, lactose, dextrose, then fructose.

When the food samples were analyzed, most analytes could be successfully identified. However, the retention times were closer than in Zaky et al. This caused many of the peaks to be unresolved, or overlapping. To integrate peaks successfully, they need to be resolved. Peak deconvolution was performed instead of changing the experimental design such as increasing column length. MagicPlot 3.0.1 was used by adding the "Lorentzian-A" function over all overlapping peaks (**Figure 5**.) However, the sucrose and lactose peaks were too close; peak deconvolution could not resolve them because they likely merged into one peak. No spectra for potato chips had a sucrose and lactose peak. Given their retention times differed by 0.1min, this is plausible.

Figure 5: The chromatogram of Classic Lay's® before and after peak deconvolution



While calibration curves could relate the signal to the concentration of the analyte in the HPLC, sample preparation caused the concentration to differ from the original sample. Calculations were done to find the mass of the analyte per serving size (see Appendix, **Table 3**.) While nutrition labels are not exact, they can provide a range of acceptable values to ensure HPLC calculations are within range. For example, Cool Ranch Doritos® has 190mg sodium, 50mg potassium, and 30mg calcium in one serving. Even if all the sodium, potassium, and calcium came from their chloride salts, 270mg does not compare to the 1400mg the HPLC read. This is way outside the 20% margin of error the FDA allows. This occurred with all of the chloride measurements, but not any of the sugars. Upon inspection of the chloride calibration curve, the y-intercept value is much higher than the rest: 0.5639 versus all others lower than 0.1. The value should be close to zero, since no concentration should yield no signal. When constructing calibration curves, the chloride had to be much more concentrated than the sugars to be detected. The sugars caused enough refraction in low concentrations to have a lower detection limit. The same could not be said for the salt, so the baseline noise could have impacted the integration of the small chloride peaks. Salt does not appear to refract light as much as sugars.

While they did not interfere with the analytes of interest, there were additional peaks that eluted long after fructose in the 20-30 minute region. The molecules eluted after fructose would be less negatively charged, or even positively charged. In Zaky et al., these compounds were organic acids such as lactic acid, acetic acid, and formic acid. The potato chips with the most prominent peaks in this region are the Salt and Vinegar Lay's®, where acetic acid is the focus of the flavor (see Appendix, **Spectra 6**.)

Analysis of Crude Fat Data

Due to the United States using total fat as their nutrition label metric and the MAE extracting crude fat, the fat content was expected to be slightly *larger* than the nutrition label. However, it was smaller than the expected value (see Appendix, **Table 4**). Total fat per serving size is 10g for Cheetos®, Classic Lay's®, Salt and Vinegar Lay's®, Sour Cream and Onion Lay's®, Cheddar and Sour Cream Ruffles®, and Munchos®. However, the crude fat content was 7.21g, 7.68g, 8.92g, 7.24g, 9.12g, and 7.34g, respectively. Any measurements lower than 8g are outside the FDA's range, so the MAE was not successful at measuring all crude fat content. The extraction vessels used during this investigation had flexible tops that did not seem as durable as plastic or glass ones. During some failed trials, the stir bar failed to sufficiently stir, causing the solvent to boil over and escape. While the data from these trials were discarded, the boiling over does indicate liquid could escape.

Statistical Analysis- The Correlation between Macronutrient Levels and Food Type

Once all the analytes per serving size were calculated, their ratios were simplified. For a potato chip flavor, all of its concentrations were divided by the smallest, which was fructose for all except Munchos, where no fructose was found. The final ratios are in **Table 1**.

Table 1: Final, Simplified Ratios

	Salt	Sucrose	Lactose	Dextrose	Fructose	Total Sugars	Fat
Red Doritos	4.511041		3.24615847	2.13703511	1	6.38319358	18.38867194
Blue Doritos	3.423568		1.773642377	1.80448793	1	4.578130306	23.37075053
Classic Lays	6.994409	1.759553585		3.63830753	1	6.397861118	53.66738571
Sour cream Lays	8.322383		4.765960264	4.69873937	1	10.46469963	62.88078247
Salt and vin Lays	9.136377	2.913936245		3.56502129	1	7.478957531	60.17804379
Cheetos	6.257521		2.873683065	2.5590435	1	6.432726568	38.85252035
Cheddar Ruffles	20.3498		9.063635301	9.08874941	1	19.15238471	170.6138653
Sun Chips	1.681235		2.300339814	2.57018743	1	5.870527248	7.320860816
Munchos	4.050292	1		1.06104739		2.061047392	27.21792472

Before conducting the MANOVA, a few smaller statistical tests were done first. First, a Grubbs test was conducted on all HP chips. Since its fructose concentration was much smaller before simplifying, this caused all of Cheddar Ruffles® values to be outliers, so its data was not considered.

All analytes were tested individually before running the MANOVA. A two-sample t-test was conducted to compare their HP and NHP values. For example, chloride measurements from Doritos®, Lay's®, and Cheetos® were compared against Sun Chips and Munchos® to see if they were significantly different from each other. Sucrose and lactose could not be tested because they only had one NHP value each. For a more accurate statistical test in the future, more NHP data sets should be considered. Therefore, only chloride, dextrose, total sugars, and crude fat was compared. At the 95% confidence level, none of the analytes had a significant difference in values between HP and NHP chips.

Finally, all analytes were compared against each other in the MANOVA. Independent variables were HP vs NHP, while dependent variables were chloride, sucrose/lactose, dextrose, fructose, total sugars, and crude fat. Sucrose and lactose were condensed into one group since the MANOVA cannot run with missing observations. According to the Wilks' Lambda test results, lambda is associated with a p-value much higher than the significance level 0.05 (**Figure 6**.) Therefore, the null hypothesis cannot be rejected. Lambda is also high, suggesting there is a high amount of unexplained variance. The independent variables, HP and NHP, have no significant effect on the macronutrient ratios.

Figure 6: Wilks' Lambda Test Results

Wilks' test (Rao's approximation):

	Food Type
Lambda	0.526
F Observed values	0.300
DF1	6
DF2	2
F Critical value	19.330
p-value	0.894

H0: The variable or the interaction of the corresponding column has ***no significant effect*** *on the dependent variables.*

Ha: The variable or the interaction of the corresponding column has a significant effect on the dependent variables.

Q1: As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is 89.36%.

Conclusion

Statistical tests suggest there is no relationship between food type (HP vs. NHP) and the ratio of macronutrients in them. Between HP and NHP chips, there were no significant differences between chloride, dextrose, total sugars, and crude fat alone. The MANOVA also showed food type had no significant effect on its macronutrient levels. Human taste perception is extremely nuanced, it would be surprising if hyper-palatable foods could be explained by a simple ratio between three macronutrients. For further study, more variables could be examined such as crunch and surface area:volume ratio. More extensive studies could begin to examine the possibility of a "bliss range" for tastier, healthier, and cheaper foods.

References

(1) Moss, M. The Extraordinary Science of Addictive Junk Food. *The New York TImes*. 2013.

(2) DiFeliceantonio, A. G. Supra-Additive Effects of Combining Fat and Carbohydrate on Food Reward. *Cell Metab.* **2018**, *28*, 33–44. https://doi.org/10.1016/j.cmet.2018.05.018.

(3) Malmendal, A. NMR Spectrometers as 'Magnetic Tongues': Prediction of Sensory Descriptors in Canned Tomatoes. *J. Agric. Food Chem.* **2011**, *20*, 10831–10838. https://doi.org/10.1021/jf203803q.

(4) Shepherd, G. A New Vision for the Science of Human Flavor Perception. *Front. Intergrative Neurosci.* **2014**, *9*. https://doi.org/10.3389/conf.fnint.2015.03.00010.

(5) Witherly, S. *Why Human's Like Junk Food: Food Pleasure Explained*; IUniverse Inc, 2007.

(6) Fazzino, T. L.; Rohde, K.; Sullivan, D. K. Hyper‐Palatable Foods: Development of a Quantitative Definition and Application to the US Food System Database. *Obes. J. 11*, 1761–1768.

(7) Arranz, L. I. Chapter 13 - Effects of Obesity on Function and Quality of Life in Chronic Pain. In *Nutritional Modulators of Pain in the Aging Population*; 2017; pp 151–170.

(8) Madhusha. Difference Between Glucose and Dextrose. *PEDIAA*. October 12, 2017.

(9) Shin, J. M. Comparison of Different Methods to Quantify Fat Classes in Bakery Products. *Food Chem.* **2013**, *2*, 703–709.

(10) C.T. Srigley; M.M Mossoba. Current Analytical Techniques for Food Lipids. *Food Drug Adm. Pap.* **2017**, 33–64.

(11) Medallion Labs. Nutrition Labels 101: What's Required? What's Optional?, 2017.

(12) Freuman, T. D. When Nutrition Labels Lie. *U.S. News*. August 21, 2012.

(13) Zaky, A. S. A New HPLC Method for Simultaneously Measuring Chloride, Sugars, Organic Acids and Alcohols in Food Samples. *J. Food Compos. Anal.* **2017**, *56*, 25–33.

(14) Wright, C. *Paper Chromatography Can Be Used to Make Artwork*; 2020.

(15) Sulfonated Polystyrene Microspheres. *EPRUI Biotech Co. Ltd*.

(16) Kobayashi, J. 5.35 - Biomaterials: Temperature-Responsive Polymer. In *Comprehensive Biotechnology*; Elsevier, 2019; Vol. 5, pp 457–470.

(17) Rhiannon. Why Couldn't the Plants Escape Prison? *University of Surrey*. November 27, 2019.

(18) Hagen, M. Lactose Structure, Intolerance & Molecule. *study.com*.

(19) Leo M.L. Nollet; Fidel Toldrá. HPLC Determination of Carbohydrates in

Foods. In *Food Analysis by HPLC*; Taylor and Francis Group; pp 243–244.
(20) Matthieu Virot. Microwave-Integrated Extraction of Total Fats and Oils. *J. Chrromatography A* **2008**, *1196*, 57–64.
(21) Ramalhosa, M. J. Lipid Content of Frozen Fish: Comparison of Different Extraction Methods and Variability during Freezing Storage. *Food Chem.* **2012**, *131*, 328–336. http://dx.doi.org/10.1016/j.foodchem.2011.07.123.
(22) Multivariate Analysis of Variance (MANOVA) in Excel Tutorial.
(23) Hunter, I. A Definitive List of Chip Flavours Ranked from Worst to Best. *dished*. March 20, 2019.
(24) Ellis, K. Popular Chip Brands Ranked Worst To Best. *Mashed*. October 28, 2021.
(25) Olito, F.; Yuan, Y. The Most Popular Brand of Chips in Every State. *Insider*. March 20, 2019.
(26) Johnston, Z. The Best Chips In The World, According To The Masses. *Uproxx*. August 31, 2017.
(27) Kaminski, L. We Tried 9 Kinds of Lay's Potato Chips—Here's Our Definitive Ranking. *Taste of Home*. April 29, 2020.
(28) What Is America's Favorite Chip Flavor? *FAQ-ANS*, 2021.

Acknowledgements

Many thanks to Dr. An-Phong Le, my research advisor, for his guidance and troubleshooting in the lab. I would also like to thank Florida Southern College for its funding and teaching me the skills to complete this project.

Appendix

Table 2: Average retention times for all analytes of interest

Analyte	Avg RT
Chloride	9.67925
Sucrose	11.60025
Lactose	11.775
Dextrose	13.45266667
Fructose	14.614

Figure 7: Calibration curve of signal vs. concentration (g/L) for chloride

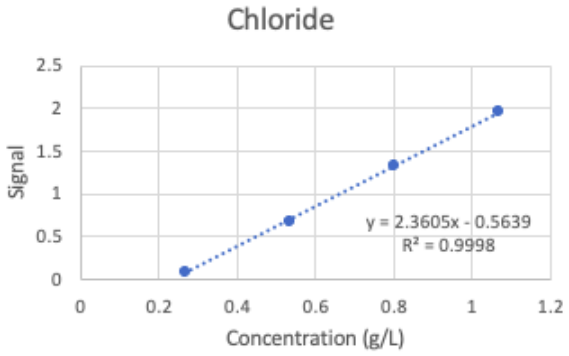


Figure 8: Calibration curve of signal vs. concentration (g/L) for sucrose

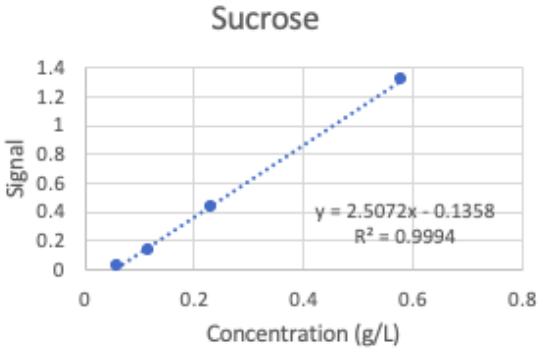


Figure 9: Calibration curve of signal vs. concentration (g/L) for lactose

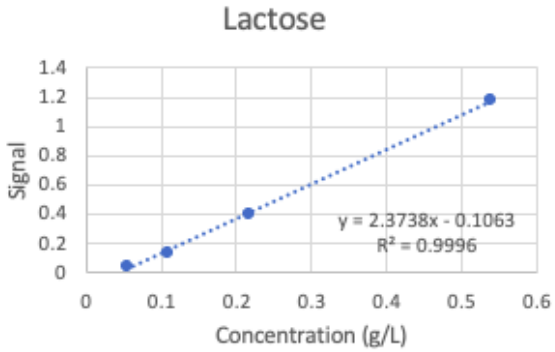


Figure 10: Calibration curve of signal vs. concentration (g/L) for dextrose

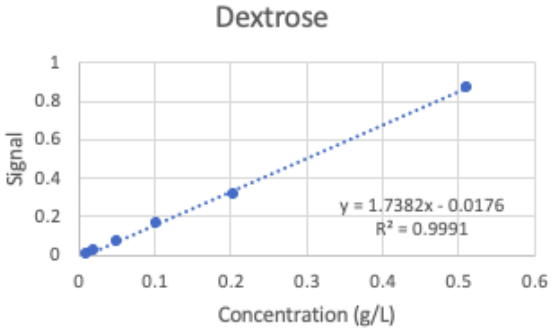
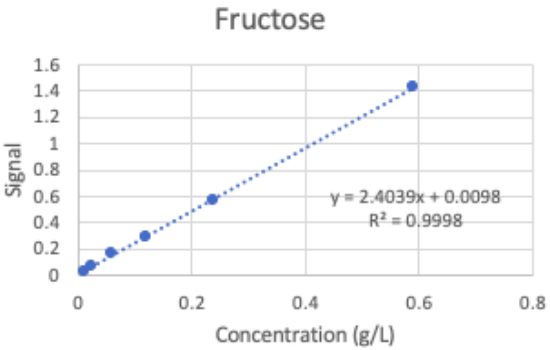
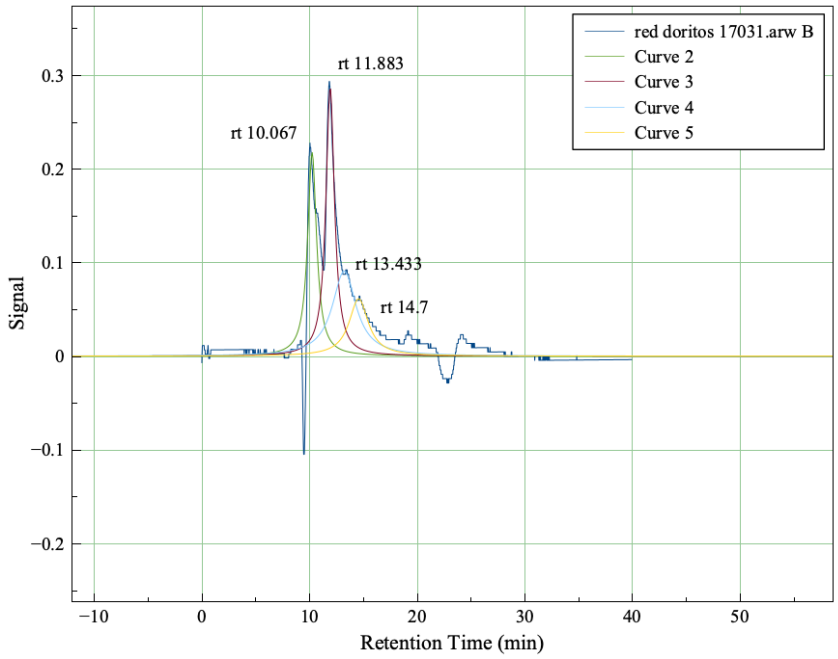


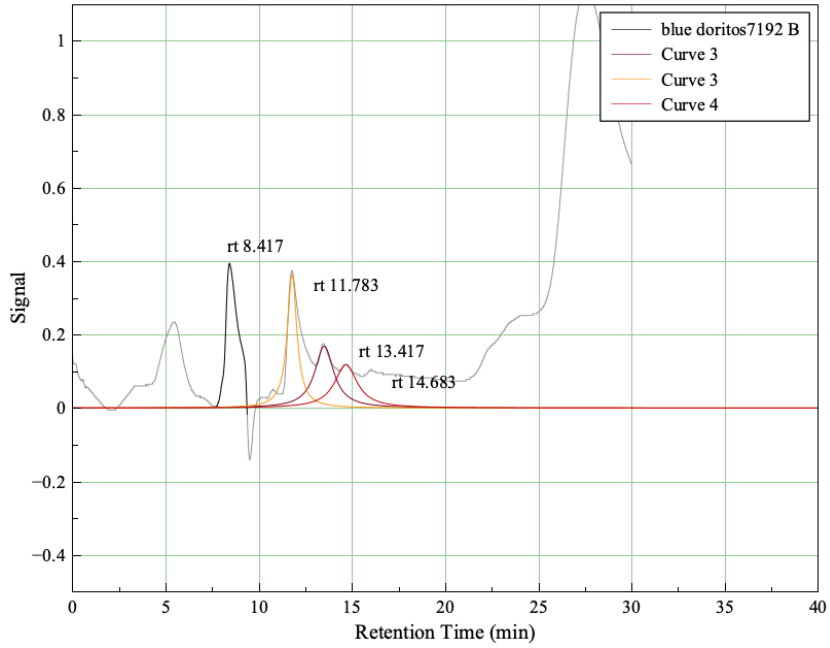
Figure 11: Calibration curve of signal vs. concentration (g/L) for fructose



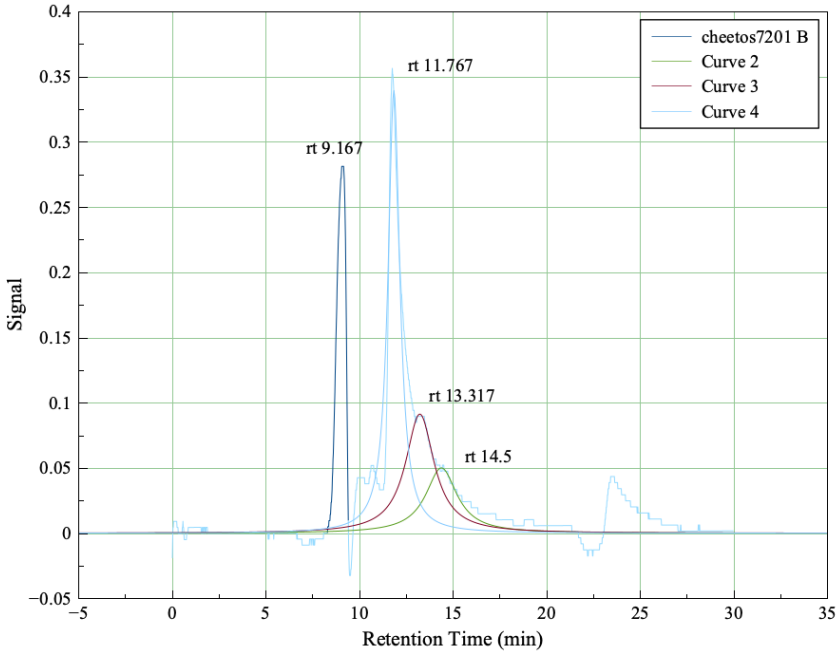
Spectra 1: HPLC Chromatogram of Nacho Cheese Doritos®



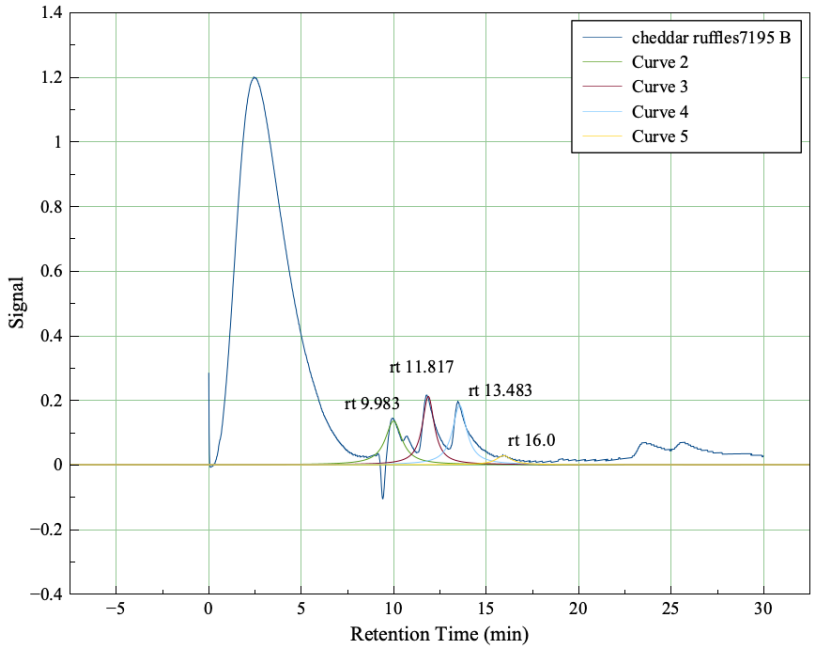
Spectra 2: HPLC Chromatogram of Cool Ranch Doritos®



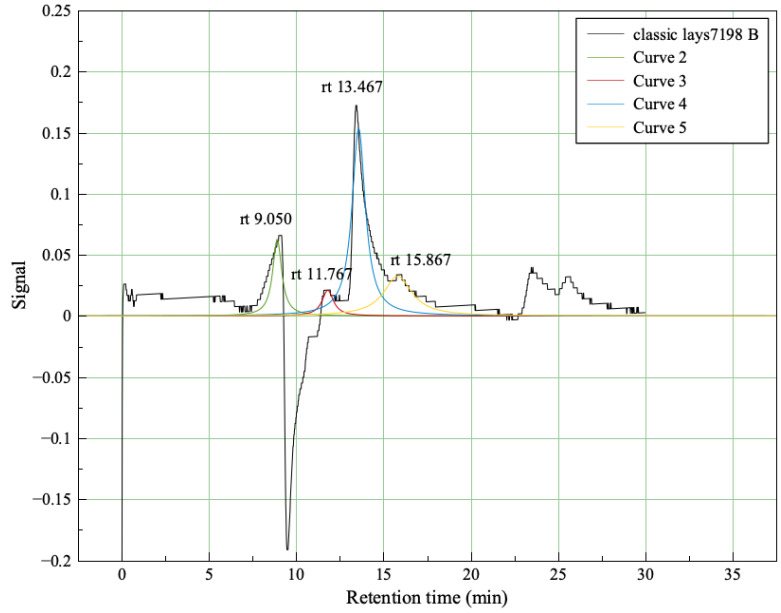
Spectra 3: HPLC Chromatogram of Cheetos®



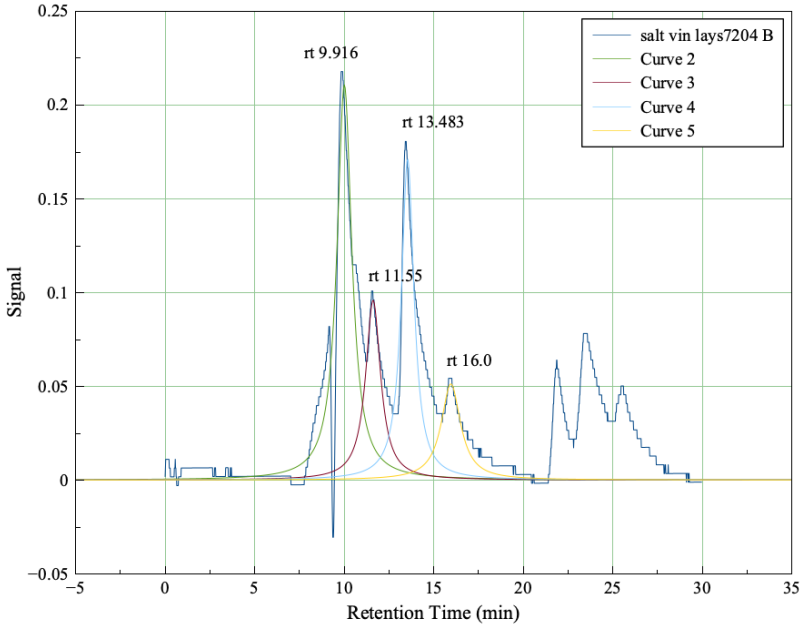
Spectra 4: HPLC Chromatogram of Cheddar and Sour Cream Ruffles®



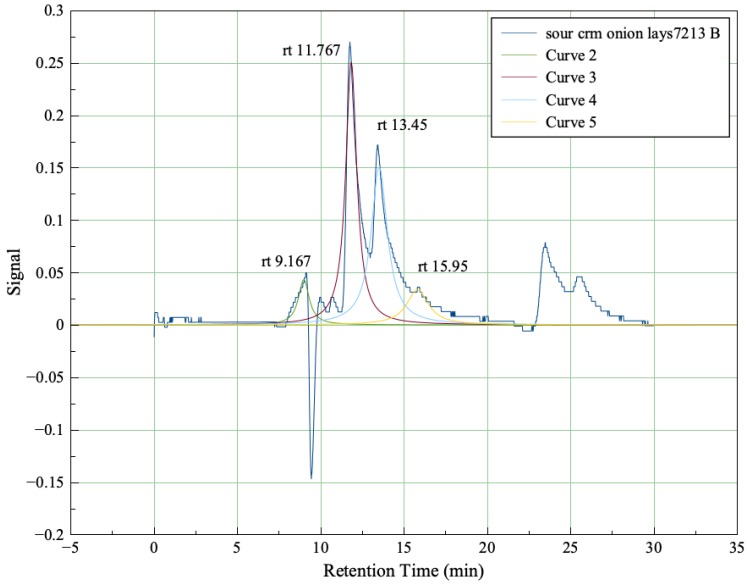
Spectra 5: HPLC Chromatogram of Classic Lay's®



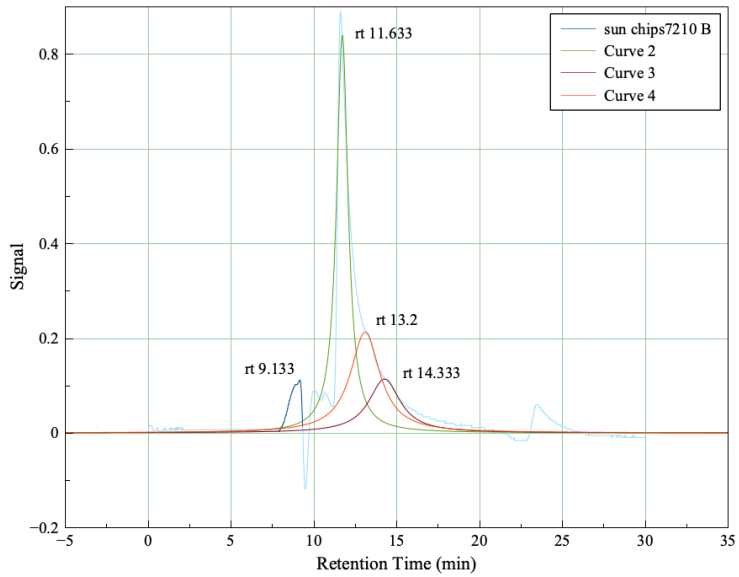
Spectra 6: HPLC Chromatogram of Salt and Vinegar Lay's®



Spectra 7: HPLC Chromatogram of Sour Cream and Onion Lay's®



Spectra 8: HPLC Chromatogram of Harvest Cheddar Sun Chips



Spectra 9: HPLC Chromatogram of Munchos®

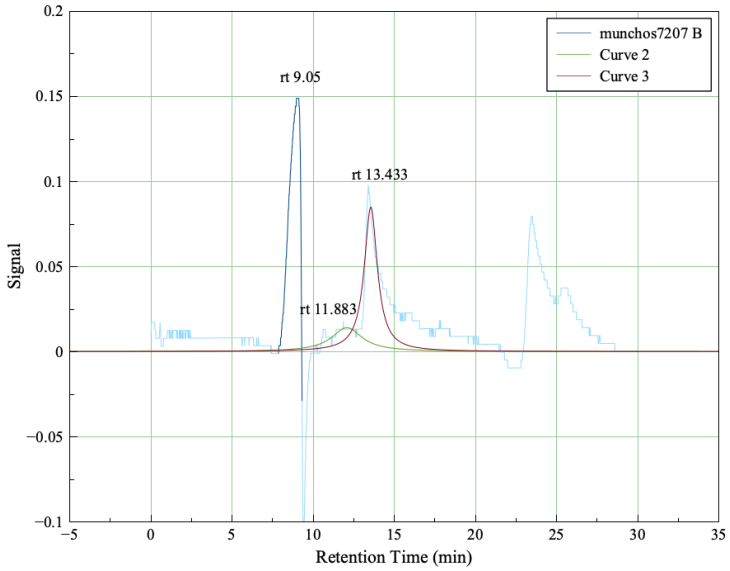


Table 3: HPLC data characterization and subsequent calculations of final amounts per serving size

Sample Name	Weight	RT	Identity	Signal	Concentration in HPLC (g/L)	Concentration in 40mL (g/L)	Mass (g) in 40 mL	Mass (g) in 1g chips	Mass (g) per Serving Size
Red Doritos	4.0859	10.067	NaCl	0.1754	0.313196357	4.228150816	0.169126033	0.041392602	1.158992857
		11.85	Lactose	0.4287	0.225377033	3.04258994	0.121703598	0.02978624	0.834014717
		13.45	Dextrose	0.2403	0.148371879	2.003020366	0.080120815	0.019609098	0.549054752
		14.667	Fructose	0.1767	0.069428845	0.937289405	0.037491576	0.009175843	0.256923599
Blue Doritos	4.0089	8.417	NaCl	0.3152	0.372421097	5.027684813	0.201107393	0.05016523	1.404626454
		11.783	Lactose	0.3517	0.192939591	2.604684472	0.104187379	0.025989019	0.727692536
		13.417	Dextrose	0.3236	0.196295018	2.649982741	0.10599931	0.026440996	0.740347893
		14.683	Fructose	0.2713	0.108781563	1.468551104	0.058742044	0.014652908	0.410281433
Classic Lays	4.0016	9.05	NaCl	0.0611	0.264774412	3.574454565	0.142978183	0.035730254	1.000447099
		11.767	Sucrose	0.0312	0.066608168	0.899210274	0.035968411	0.008988507	0.251678206
		13.467	Dextrose	0.2218	0.137728685	1.859337245	0.07437349	0.018585938	0.520406266
		15.867	Fructose	0.1008	0.037855152	0.511044553	0.020441782	0.005108402	0.143035261
Sour Cream Lays	4.001	9.117	NaCl	0.0343	0.253420885	3.421181953	0.136847278	0.034203269	0.957691524
		11.767	Lactose	0.2382	0.145125958	1.959200438	0.078368018	0.019587108	0.548439013
		13.45	Dextrose	0.2311	0.143079047	1.931567138	0.077262686	0.019310844	0.540703623
		15.95	Fructose	0.083	0.030450518	0.411081992	0.01644328	0.004109792	0.115074189
Salt + vin Lays	4.008	9.9	NaCl	0.2839	0.359161195	4.848676128	0.193947045	0.048389981	1.354919477
		11.55	Sucrose	0.1514	0.114550096	1.546426292	0.061857052	0.015433396	0.432135092
		13.483	Dextrose	0.226	0.140144978	1.891957197	0.075678288	0.018881808	0.528690634
		15.95	Fructose	0.1043	0.039311119	0.530700112	0.021228004	0.005296408	0.148299433
Cheetos	4.0093	9.117	NaCl	0.163	0.307943232	4.157233637	0.166289345	0.041475905	1.161325337
		11.767	Lactose	0.2294	0.141418822	1.909154099	0.076366164	0.019047256	0.533323171
		13.283	Dextrose	0.2013	0.125934875	1.700120815	0.068004833	0.016961772	0.474929617
		14.517	Fructose	0.1281	0.049211698	0.664357918	0.026574317	0.006628169	0.185588723
Cheddar Ruffles	4.0146	9.967	NaCl	0.1175	0.288667655	3.897013345	0.155880534	0.03882841	1.087195473
		11.817	Lactose	0.1989	0.128570225	1.735698037	0.069427921	0.017293858	0.484228018
		13.483	Dextrose	0.2065	0.128926476	1.740507421	0.069620297	0.017341777	0.485569748
		15.917	Fructose	0.0439	0.014185282	0.19150131	0.007660052	0.001908049	0.053425364
Sun Chips	4.0021	9.033	NaCl	0.0915	0.27765304	3.748316035	0.149932641	0.037463492	1.048977776
		11.633	Lactose	0.7955	0.379897211	5.128612352	0.205144494	0.051259212	1.435257948
		13.117	Dextrose	0.7202	0.424462087	5.730238177	0.229209527	0.057272314	1.603624787
		14.283	Fructose	0.4068	0.165148301	2.229502059	0.089180082	0.022283322	0.623933012
Munchos	3.9967	9.033	NaCl	0.1183	0.289006566	3.901588646	0.156063546	0.039048101	1.093346832
		11.883	Sucrose	0.0431	0.071354499	0.963285737	0.038531429	0.009640811	0.269942709
		13.416	Dextrose	0.114	0.075710505	1.022091819	0.040883673	0.010229357	0.286422008

Table 4: Gravimetric Determination of Crude Fat

Sample Name	Weight	Flask weight before (g)	Flask weight after (g)	SFC (g)	SFC (g) per serving size
Red Doritos	0.1695	89.0398	89.0684	0.0286	4.724483776
Blue Doritos	0.1682	91.0021	91.0597	0.0576	9.588585018
Classic Lays	0.1656	89.0778	89.1232	0.0454	7.676328502
Sour Cream Lays	0.1691	98.6101	98.6538	0.0437	7.235955056
Salt + vin Lays	0.1666	89.1357	89.1888	0.0531	8.924369748
Cheetos	0.1662	91.0352	91.078	0.0428	7.210589651
Cheddar Ruffles	0.1668	91.079	91.1333	0.0543	9.115107914
Sun Chips	0.1698	98.6613	98.689	0.0277	4.567726737
Munchos	0.1673	91.1348	91.1787	0.0439	7.347280335