

**An investigation of the role of processed foods in children's health: classification,  
perceptions, dietary quality and weight status**

A thesis presented to the faculty of the  
Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy

by

Rachel Bleiweiss-Sande, MS

in partial fulfillment of requirements for the  
Degree of Doctor of Philosophy in Food Policy and Applied Nutrition

Tufts University

April 2019

**Thesis Committee Chair and Advisor**

Jennifer Sacheck, PhD, FACSM  
Tufts University Friedman School of Nutrition Science and Policy

**Committee Members**

Kenneth K.H. Chui, MPH, PhD  
Tufts University School of Medicine, Department of Public Health and Community  
Medicine

E. Whitney Evans, PhD, RD  
Warren Alpert School of Medicine

Jeanne Goldberg, PhD, RD  
Tufts University Friedman School of Nutrition Science and Policy

**DEDICATION**

This dissertation is dedicated to the small group of people who I am lucky enough to call family.

To my mom, who sacrificed everything.

To my aunt Laura, who taught me to be a lifelong learner.

And to my dad, who would have been proud.

## ACKNOWLEDGMENTS

The Friedman School is a unique and wonderful place. Since the time I arrived in Richard Moyer's office circa Fall 2013 I've felt welcomed, supported and very much at home. I am personally thankful to several writing professors, Laurie LaRusso and Patrick Skerret. Both pushed me to write more clearly about nutrition, a requisite and still evolving skill that was put to work during my doctorate. My journey through the School would also not have been possible without the help of many Friedman staff who keep everything running smoothly. In particular, I'd like to thank Lori Ioannone, Isabel McFall, Patty Dawson and Michelle Frankfurt for their hard work and attention to detail.

I could not have asked for a better committee of mentors to approach the daunting task of building a dissertation. As individuals, each of you contributed the materials and tools to put up the scaffolding. As a group, you helped me construct it from the ground up. Thank you for being such a dream team.

I will always think of Jeanne Goldberg as my nutrition fairy godmother. Jeanne, there is no one who can get to the heart of the matter more nimbly or come to a decision more adroitly than you. You have a way with words that I admire and strive to emulate in my own writing. I take great comfort in knowing that your office door is always open for an on the fly editing session or pep talk. The support and guidance that you've offered to me has gone above and beyond. Thank you.

When Whitney Evans agreed to not only share her data, but also serve as a member of my dissertation committee, I knew that everything would work out. Whitney, it has truly been a pleasure to learn, work, and grow under your guidance throughout the PhD process. Your professionalism (and style!) are inspiring, and your thoroughness has provided a model for the type of research I'd like to be a part of in the future.

Ken Chui has a capacity for patience that is the stuff of legends, and an almost magical ability to make the statistically-uninclined feel confident. As a teacher, Ken, your generosity and commitment to students is unparalleled. Far from the initial wave of nausea that I felt during my first statistics class at Friedman, taking your course, and later working with you on the analysis for this dissertation, has convinced me that statistics is fun.

Jen Sacke is a real-life superwoman. When she agreed to take me under her wing as an advisee, she had just given birth to her third beautiful child. Jen is the only person I know who could simultaneously take on a new department chair position, a new baby and a new doctoral student, all with humor and grace. Jen, thank you for believing in me. Thank you for pushing me when I needed it and for propping me up during rocky times. Thank you for teaching me to see the forest through the trees. Working under your leadership has certainly taught me how to be a better researcher, but more importantly it's forced me to be a better person.

Through working on this dissertation I had the chance to work with several wonderful schools and communities. I am grateful to the school administrators who made this research possible, and to every participant who brought energy and truth to this project.

Catherine Wright and Paula Duquesnay, the duo that we so affectionately referred to as the "FLEX team," should really be regarded as the kind of secret weapons that you never, ever reveal for fear of someone else stealing them away. Both of you contributed

so much to this project, from hours spent taking notes during focus groups to much needed smiles and check-ins at the office. You are both brilliant and beautiful women that I feel honored to call friends.

I was fortunate enough to work with two directed study students, Alejandra Cabrera and Caitlin Bailey, on several sections of this dissertation. I am forever indebted to each of them for the long hours of transcribing and analysis prep. Caitlin stuck with me for another year, spending countless hours by my side as we pondered the philosophical conundrum of defining “processed food.” Caitlin, I’m so thankful for your invaluable research help, and more importantly for being an awesome friend. I can’t wait to see where you go next!

This section would not be complete without calling out the many Friedman peers and colleagues that have buoyed me with their support, encouragement and friendship. Thank you Meghan Mueller, Stacy Blondin, Lindsay Tanskey, Nicole Shultz, Megan Lehnerd and Dan Hatfield for always providing sage advice. The daily check-ins from friends like Mehreen Ismail, Reem Alsukait, Ashley McCarthy and others in my PhD cohort kept me going. And a big thank you to Ariella Korn for being the best desk-mate, bike partner and friend in the whole world!

Mom, thank you for teaching me to love food, cooking, health, and exercise, the passions that eventually led me to the field of nutrition. You’ve always been my biggest cheerleader, and I promise to call you back much more often now that the dissertation is done! Thank you for being the best mom ever.

Laura, the dissertation experience has brought us closer in ways that I never anticipated, and that on its own has made these past years worth it. You have served as a mentor, role model, advisor and friend, and I really could not have done it without you. Thank you for coaxing me to find my own, unique path to success.

Eric, thank you for sticking with me throughout the long journey of this dissertation. You’ve been by my side for every high point and fall. Your constant reminder to believe in myself has kept me going. I am so thankful for our relationship.

This dissertation would not have been possible without support from several generous foundations, including the Friedman Nutrition and Citizenship Fellowship, Boston Nutrition Obesity Research Center, and the Boston Foundation.

## ABSTRACT

Highly processed food consumption has consistently been singled out as a potential factor in the obesity epidemic, particularly among disadvantaged children. To explore that relationship, researchers have developed classification systems that categorize foods according to processing level. Discrepancies among these systems have led to varying conclusions, such that our understanding of how processed food intake contributes to weight status and income-related health disparities is limited. Moreover, agreement between consumer perceptions and research definitions of processed foods has not been measured. This limits the usefulness of this concept in consumer communication. These issues were addressed through three independent studies.

The first study compared processing categorization and subsequent conclusions regarding the relationship between processing level and nutrient quality among three classification systems used in research (Nova, International Food Information Council (IFIC), UNC), using the 100 most commonly consumed foods by children, ages 6–12 (NHANES 2013-2014). Inter-rater reliability was highest for the UNC system ( $\rho = 0.97$ ), and lowest for Nova ( $\rho = 0.76$ ). Multinomial logistic regression models demonstrated that lower potassium was a significant predictor of moderately compared to minimally processed foods in the IFIC system ( $p=0.01$ ), and lower vitamin D was predictive of highly compared to minimally processed foods for UNC ( $p=0.04$ ). Greater sodium and added sugars were significantly predictive of high compared to minimal processing level for all three systems ( $p<0.05$ ), suggesting that current processing classification systems may be well suited to identify over-consumed nutrients among children.

The second study used focus groups to explore how children ( $n=53$ ) and parents ( $n=37$ ) from low-income and racially/ethnically diverse backgrounds think about processed foods, including the meaning of phrases related to processing, the classification of foods by processing level, and the healthfulness of foods. Transcript analysis using NVivo 12 indicated that their understanding was not always consistent with classification systems used in research. Participants associated degree of processing with healthfulness, suggesting that the topic of processing may offer a novel approach for nutrition communication.

The third study examined associations between processed food intake, dietary quality and weight status among 131 racially/ethnically diverse school-age children from low-income communities in Rhode Island. Twenty-four hour dietary recalls were collected and coded by processing level. Associations between dietary quality, as measured by the Healthy Eating Index, 2015 (HEI-2015) and weight status were analyzed using multivariate linear regression models. Greater intake of highly processed food was associated with lower dietary quality ( $\beta=-0.23$ , 95% CI [-0.30, -0.15]), while greater intake of minimally processed foods was associated with higher dietary quality ( $\beta=0.30$ , 95% CI [0.22, 0.38]). No significant associations between processed food consumption and weight were observed. This suggests that encouraging minimally processed and discouraging highly processed food consumption may be synergistic communication strategies to improve diet quality in children from low-income backgrounds.

This research demonstrates that observations about the effects of processed foods on obesity and diet quality depend on the classifications systems used in studies of that relationship. The development of a consistent definition of processed foods will not only lead to a clearer understanding of their effects on health, but will also enable the concept to be translated into consumer communications.

## TABLE OF CONTENTS

|                                                                                                           |      |
|-----------------------------------------------------------------------------------------------------------|------|
| DEDICATION .....                                                                                          | i    |
| ACKNOWLEDGMENTS .....                                                                                     | ii   |
| ABSTRACT.....                                                                                             | iv   |
| LIST OF TABLES AND FIGURES.....                                                                           | viii |
| LIST OF ABBREVIATIONS & ACRONYMS .....                                                                    | x    |
| CHAPTER I: INTRODUCTION.....                                                                              | 1    |
| Problem & Significance.....                                                                               | 1    |
| Specific Aims & Hypotheses .....                                                                          | 1    |
| CHAPTER II: REVIEW OF THE LITERATURE .....                                                                | 6    |
| Overview.....                                                                                             | 6    |
| Classifying foods by degree of processing .....                                                           | 7    |
| Perceptions and understanding of processed foods .....                                                    | 9    |
| Processed food consumption and weight status.....                                                         | 13   |
| Processed food consumption and diet quality.....                                                          | 15   |
| Summary .....                                                                                             | 16   |
| CHAPTER III: Alignment of food processing classification systems with nutrient quality<br>.....           | 24   |
| CHAPTER IV: Chemicals, cans and factories: how grade school children think about<br>processed foods ..... | 45   |
| CHAPTER V: Perceptions of processed foods among low-income and immigrant parents<br>.....                 | 65   |

|                                                                                                                                                               |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| CHAPTER VI: Associations between processed food consumption, dietary quality and weight status in a sample of low-income and ethnically diverse children..... | 83  |
| CHAPTER VII: SUMMARY & DISCUSSION .....                                                                                                                       | 104 |
| Introduction.....                                                                                                                                             | 104 |
| Summary of methods and results .....                                                                                                                          | 105 |
| Aim 1: Current food classification systems in the U.S. ....                                                                                                   | 105 |
| Aim 2: Child and parent perceptions of processed foods .....                                                                                                  | 109 |
| Aim 3: Associations between processed food consumption, diet quality and weight status .....                                                                  | 112 |
| Issues related to current classification systems used in research.....                                                                                        | 115 |
| Implications for policy and communication .....                                                                                                               | 119 |
| Directions for future research .....                                                                                                                          | 120 |
| Suggestions for expansion on the present work.....                                                                                                            | 121 |
| Conclusion .....                                                                                                                                              | 122 |
| APPENDICES .....                                                                                                                                              | 129 |
| Appendix A: Aim 1 Supplementary materials .....                                                                                                               | 129 |
| A.1: The top 100 foods categorized by processing level using three processing frameworks .....                                                                | 129 |
| A.2: Comparison between top 100 foods according to count, weight, and servings consumed per day .....                                                         | 132 |
| Appendix B: Aim 2 Supplementary materials .....                                                                                                               | 137 |

|                                                             |     |
|-------------------------------------------------------------|-----|
| B.1: Child focus group recruitment materials .....          | 137 |
| B.2: Parent focus group recruitment materials .....         | 138 |
| B.2: Guide for child focus groups .....                     | 139 |
| B.3: Focus group guide for parent focus groups .....        | 143 |
| B.4: Activity cards for child and parent focus groups ..... | 148 |
| Appendix C: Aim 3 Supplementary materials .....             | 149 |
| C.1: Sensitivity analysis, analytic approach .....          | 149 |
| C.2: Sensitivity analysis, weighting approach .....         | 150 |
| C.3: Mediation analysis .....                               | 151 |

## LIST OF TABLES AND FIGURES

|                                                                                                                                                                                                                                                                                   |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Table 1:</b> Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing according to the IFIC, Nova and UNC systems....                                                                                               | 40  |
| <b>Table 2:</b> Mean nutrient concentration per standard portion of the top 100 foods consumed by children 6–12 years old by processing level for the IFIC, Nova and UNC systems, NHANES 2013-2014 .....                                                                          | 41  |
| <b>Table 3:</b> Multinomial logistic regression results for the association between classification level as determined by the IFIC, Nova and UNC processing classification systems and nutrients of concern among 6–12 year olds in the U.S. population, NHANES 2013-2014 .....   | 42  |
| <b>Table 4:</b> Sociodemographic characteristics of child focus group participants (N = 53) .....                                                                                                                                                                                 | 62  |
| <b>Table 5:</b> Sample quotes and example foods to support children's descriptions of terms related to processing .....                                                                                                                                                           | 63  |
| <b>Table 6:</b> Quotations to support themes related to how children classify foods by processing level .....                                                                                                                                                                     | 64  |
| <b>Table 7:</b> Demographic characteristics, by immigrant status, of parents from three urban school districts participating in a focus group study on the topic of processed foods during Spring 2018 (N=37).....                                                                | 80  |
| <b>Table 8:</b> Sample quotes and example foods to support participant's descriptions of terms related to processing, by immigrant status, from a focus group study of parents from three urban school districts on the topic of processed foods during Spring 2018 (N = 37)..... | 81  |
| <b>Table 9:</b> Parent quotations to support classification of foods according to processing level, by theme from a focus group study of parents from three urban school districts on the topic of processed foods during Spring 2018 (N = 37).....                               | 82  |
| <b>Table 10:</b> Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing.....                                                                                                                                         | 99  |
| <b>Table 11:</b> Demographic characteristics, children participating in the Summer Food Service Study (N=131).....                                                                                                                                                                | 100 |
| <b>Table 12:</b> Dietary characteristics by weekday vs. weekend, children participating in the Summer Food Service Study (N=131).....                                                                                                                                             | 101 |

|                                                                                                                                                                                                                                                                                                                                              |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Table 13:</b> Results of linear regression models quantifying the relationship between percent of calories from processing level9 per intake day with Healthy Eating Index 2015 score among children participating in the Summer Foodservice Study (N=131).....                                                                           | 102 |
| <b>Table 14:</b> Results of linear regression models quantifying the relationship between percent of calories from processing level9 per intake day with age- and sex-standardized body mass index score among children participating in the Summer Foodservice Study (N=131).....                                                           | 103 |
| <b>Figure 1:</b> Original and final category assignment for foods as classified by the International Food Information Council (IFIC), Nova and University of North Carolina at Chapel Hill (UNC) systems.....                                                                                                                                | 43  |
| <b>Figure 2:</b> The top 100 foods consumed by children 6–12 years old (NHANES 2013-2014) by processing level, plotted within the first two linear discriminants for the International Food Information Council (IFIC), Nova and University of North Carolina at Chapel Hill (UNC) systems according to predicted classification level ..... | 44  |
| <b>Figure 3:</b> Social-ecological framework for organizing factors to consider in designing food processing classification systems.....                                                                                                                                                                                                     | 124 |

**LIST OF ABBREVIATIONS & ACRONYMS**

BMI: Body Mass Index

BPF: Basic processed food

CDC: Center for Disease Control and Prevention

CI: Confidence Interval

DGA: Dietary Guidelines for Americans

HEI: Healthy Eating Index

HPF: Highly processed food

IFIC: International Food Information Council

MPF: Moderately processed food

NHANES: National Health and Nutrition Examination Survey

NSLP: National School Lunch Program

SPB: School Breakfast Program

SD: Standard Deviation

SE: Standard Error

SES: Socio-economic status

SFSP: Summer Food Service Program

SSB: Sugar-sweetened beverage

UNC: University of North Carolina at Chapel Hill

U.S.: United States

USDA: United States Department of Agriculture

UPF: Unprocessed & minimally processed food

## **CHAPTER I: INTRODUCTION**

### **Problem & Significance**

Despite a recent plateau in national child obesity rates, there are underlying health disparities. Obesity prevalence continues to rise among low-income and minority youth.<sup>1-6</sup> The factors implicated in child obesity are complex, and include individual, family, environmental and social influences that interact to contribute to this health disparity.<sup>7</sup> Novel approaches to targeting obesity that consider these multiple layers of influence are urgently needed to prevent further intensification of social inequalities amongst vulnerable populations in the U.S.<sup>8,9</sup>

The global availability of highly processed food (HPF) has consistently been advanced as a potential driver of the obesity epidemic.<sup>10-12</sup> A small body of evidence suggests that over-consumption of HPFs may have particularly detrimental effects in children, including increased risk of obesity<sup>13</sup>, cardiovascular disease<sup>14-16</sup>, and metabolic syndrome.<sup>17</sup> However, research examining the relationship between HPF intake and obesity among children in the U.S. is limited, and little is known about the key behavioral, social and ecological determinants of HPF consumption. Moreover, the primary food classification system used in research to categorize foods according to their extent of processing, the Nova system, as well as conclusions stemming from use of this system, have prompted extensive criticism from the scientific community.<sup>18-20</sup> Use of alternate coding schemes, including the system developed by the International Food Information Council (IFIC), has demonstrated that processing is a minor determinant of nutrient contributions to diets.<sup>21</sup> Accordingly, the effects of processing level on diet quality, as well as the effects of processed food intake on weight status, remain controversial. Given the continued rise in social inequalities in obesity among at-risk youth, additional research is warranted to understand these inconsistent findings in the context of children's diets, as well as the relationship between HPF and total energy intake, overall dietary quality, and weight status in this population.<sup>22</sup>

### **Specific Aims & Hypotheses**

The long-term goals of this research are to provide evidence to support the need for a universal framework for classifying foods to elucidate the relationship between HPF

consumption and weight status among disadvantaged youth in the U.S. The specific aims and hypotheses to be tested are:

**AIM 1: To examine the reliability of processing level within and between three food processing classification systems, and the relationship between processing level and nutrient concentration as predicted by each framework.**

Approach: The 100 foods most commonly consumed by 6–12 year olds participating in the 2013-2014 National Health and Examination Survey (NHANES) were categorized by processing level using the Nova, University of North Carolina at Chapel Hill (UNC) and International Food Information Council (IFIC) processing classification systems by two independent coders.

Hypothesis 1a: Interrater reliability will vary significantly between systems; UNC will have the highest interrater reliability scores compared to the NOVA and IFIC systems.

Hypothesis 1b: The systems will yield significantly different results regarding the percentage of energy from highly processed products among the 100 foods used; the NOVA system will demonstrate the highest percentage from energy from HPFs compared to the UNC and IFIC systems.

Hypothesis 1c: There will be significant differences between processing level assignment and resulting conclusions regarding the relationship between nutrient concentration and processing level between classification systems; the NOVA system will demonstrate a stronger association between highly processed foods and nutrients that negatively contribute to the diet quality of Americans compared to the UNC and IFIC systems.

**AIM 2: To explore perceptions and knowledge of processed foods in terms of classification and healthfulness among 4<sup>th</sup> – 6<sup>th</sup> grade schoolchildren and their parents/caregivers, and to determine whether child and parent definitions of processing are aligned with those of researchers.**

Approach: To conduct a series of focus groups with racially and ethnically diverse children and parent/caregivers of children attending public school or afterschool programs in low-income, urban school districts in New England.

**AIM 3: To investigate the relationship between consumption of highly processed foods, diet quality and weight status among youth ages 9-12 years.**

Approach: Anthropometric and dietary data collected from children participating in an ongoing study in Rhode Island was used to assess the relationship between processed food consumption, dietary quality and weight status (BMI).

Hypothesis 3a: Higher intake of energy from HPFs will be positively associated with BMI-z score.

Hypothesis 3b: Higher intake of energy from HPFs will be inversely associated with dietary quality, considering the influences of gender, age, ethnicity and socioeconomic status.

Hypothesis 3c: Higher dietary quality will attenuate the association between processed food consumption and BMI-z score.

## REFERENCES

1. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2010;51.
2. Singh GK, Kogan MD, Yu SM. Disparities in obesity and overweight prevalence among US immigrant children and adolescents by generational status. *J Community Health*. 2009;34(4):271-281.
3. Singh GK, Siahpush M, Kogan MD. Rising social inequalities in US childhood obesity, 2003-2007. *Ann Epidemiol*. 2010;20(1):40-52.
4. Frederick CB, Snellman K, Putnam RD. Increasing socioeconomic disparities in adolescent obesity. *Proc Natl Acad Sci U S A*. 2014;111(4):1338-1342.
5. Wang Y, Beydoun MA. The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev*. 2007;29:6-28.
6. Hales C, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2017;288.
7. Anderson M, Butcher F. Childhood Obesity: Trends and Potential Causes. *The Future of Children*. 2006;16(1):19-45.
8. Sallis JF, Glanz K. Physical Activity and Food Environments: Solutions to the obesity epidemic. *The Milbank Quarterly*. 2009;87(1):123-154.
9. Hebden L, Chey T, Allman-Farinelli M. Lifestyle intervention for preventing weight gain in young adults: a systematic review and meta-analysis of RCTs. *Obes Rev*. 2012;13(8):692-710.
10. Fardet A. Food Health Potential is Primarily Due to Its Matrix Structure, then Nutrient Composition: A New Paradigm for Food Classification according to Technological Processes Applied. *Journal of Nutritional Health & Food Engineering*. 2014;1(5).
11. Carlos Augusto Monteiro RBL, Rafael Moreira Claro, Inês Rugani Ribeiro de Castro, Geoffrey Cannon A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11).
12. Rob Moodie DS, Carlos Monteiro, Nick Sheron, Bruce Neal, Thaksaphon Thamarangsi, Paul Lincoln, Sally Casswell. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet*. 2013;381:670-679.
13. Ambrosini GL. Childhood dietary patterns and later obesity: a review of the evidence. *Proc Nutr Soc*. 2014;73(1):137-146.
14. Appannah G, Pot GK, Huang RC, et al. Identification of a dietary pattern associated with greater cardiometabolic risk in adolescence. *Nutr Metab Cardiovasc Dis*. 2015;25(7):643-650.

15. Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. *Nutr Metab Cardiovasc Dis*. 2015;25(1):116-122.
16. Vitolo MR, Rauber F. Influence of Food Processing on Blood Lipids in Children. *Nutrients*. 2016;8(2):97.
17. Tavares LF, Fonseca SC, Garcia Rosa ML, Yokoo EM. Relationship between ultra-processed foods and metabolic syndrome in adolescents from a Brazilian Family Doctor Program. *Public Health Nutr*. 2012;15(1):82-87.
18. Gibney MJ, Forde CG, Mullally D, Gibney ER. Ultra-processed foods in human health: a critical appraisal. *Am J Clin Nutr*. 2017;106:717-724.
19. Dwyer JT, Fulgoni VL, 3rd, Clemens RA, Schmidt DB, Freedman MR. Is "processed" a four-letter word? The role of processed foods in achieving dietary guidelines and nutrient recommendations. *Adv Nutr*. 2012;3(4):536-548.
20. Dwyer JT. Trailblazer Lecture: Why Are Processed Foods So Controversial? *J Acad Nutr Diet*. 2015;115(11):1871-1876.
21. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003-2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S-2072S.
22. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.

## CHAPTER II: REVIEW OF THE LITERATURE

### Overview

Processed foods have existed in the human diet for over 2 million years in forms such as cured and dried meats, fermented beverages and pickled vegetables, but their role in terms of nutrition and health in modern day diets is currently under debate.<sup>1</sup> According to the U.S. Department of Agriculture (USDA), food processing refers to any procedure that alters food from its natural state.<sup>2</sup> Thus, any food aside from raw, agricultural commodities is considered processed. Because of the considerable heterogeneity across processed foods, researchers have developed classification systems to distinguish foods according to the level or complexity of processing, ranging from minimally to highly processed.<sup>3-5</sup> While it is widely accepted that modern day food processing techniques allow for a safe, abundant, and accessible food supply,<sup>6</sup> the amount of *highly* processed foods in the U.S. diet has risen to unprecedented levels, with researchers estimating that approximately 60% of calories consumed by the general population are from highly refined sources.<sup>5,7</sup>

In the U.S., childhood obesity continues to be recognized as a major public health problem. Children with overweight and obesity have an elevated risk of obesity in adulthood, contributing to health disparities that track later into life.<sup>8-10</sup> Recent evidence demonstrates that while overall obesity rates continue to rise,<sup>11</sup> the prevalence is even higher among children from lower socioeconomic status (SES) backgrounds.<sup>12,13</sup> Racial/ethnic disparities persist as well: non-Hispanic Black and Mexican children are more likely to be overweight or obese than their non-Hispanic White peers.<sup>11</sup> Shortcomings of the local food environment in disadvantaged neighborhoods may help to explain these disparities. Low-income neighborhoods tend to have a higher concentration of convenience stores and fast food restaurants, which sell energy-dense, nutrient poor foods, and limited access to supermarkets.<sup>14</sup> Thus, families in low-SES neighborhoods may be more likely to buy highly refined, shelf stable foods due to issues of food access as well as cost.<sup>15</sup>

In an effort to broaden the scope of obesity prevention, researchers and health professionals have called for closer examination of local food environments and the effects of industrial food production practices on health outcomes.<sup>16-19</sup> It is well-known

that high intakes of “junk foods,” or energy dense, nutrient-poor foods, are implicated in weight gain. These products are often highly refined, processed foods made on an industrial scale, leading some researchers to propose that excessive food processing can have negative effects on nutritional quality and health outcomes.<sup>20-23</sup> Seen in this light, extent of food processing offers a novel dietary focus for approaching obesity prevention, particularly as it relates to income-related health disparities.

### **Classifying foods by degree of processing**

In the U.S. and abroad, epidemiological research, assessments and subsequent dietary recommendations have traditionally used food group and nutrient classification schemes to examine contributors to diet-related chronic disease and convey nutrition information. Over the past decade, the use of a food classification and coding system based on the degree of processing has been promoted as a novel approach to epidemiological nutrition research.<sup>24</sup> Food group classifications, it is argued, fail to distinguish between unaltered and reformulated versions of a food — for example, fruits are often lumped into a single category that includes raw products, canned whole products and sweetened preserves or flavored items in syrup — leading to misclassification of healthy products.<sup>22</sup> In addition, by translating nutrient-based targets into food-based recommendations, dietary guidelines may encourage extreme levels of fortification by the food industry to portray HPFs as nutritious.<sup>17</sup> Processing classification may add an important dimension to food recommendations, describing the extent and purpose of industrial processes.

A systematic review of processing classification systems applied in scientific literature by Moubarac et al. identified five systems, originating from Brazil, Europe, Mexico and the U.S.<sup>25</sup> Of these, two were devised for use in middle- and lower-income countries;<sup>26,27</sup> the European system has been applied to data from the European Investigation into Cancer and Nutrition study<sup>28,29</sup>; the U.S. system, developed by the International Food Information Council (IFIC), has been used to examine the nutrient quality of foods consumed by Americans by processing category,<sup>5,30</sup> and the Brazilian system (Nova) has been applied globally.<sup>23,31-35</sup> In their review of these frameworks, the authors assess the five systems according to their level of specificity, coherence, clarity, comprehensiveness and workability, finding the Nova system to rank highest based on

these criteria.<sup>25</sup> The IFIC system ranked lowest, due to a lack of distinction between industrial and artisanal processing; lack of logical order in processing categories, and incomplete listing of example foods.<sup>25</sup> Of note, three co-authors of this review were responsible for developing the Nova framework, indicating a potential source of bias.

In the U.S., researchers at the University of North Carolina at Chapel Hill (UNC) have developed an additional system that classifies all barcoded foods items commonly sold in U.S. supermarkets according to processing level.<sup>3</sup> Development of the UNC system was guided by the Nova system, but was modified to capture the complexity of the U.S. food supply with enhanced category definitions and examples.<sup>3</sup> This system has been applied to Nielsen Homescan Panel and NHANES data to examine trends in American purchasing habits.<sup>3,36</sup>

A later systematic review and comparison of classification systems by Crino et al. identified six frameworks.<sup>37</sup> The authors applied each system to a sample of 135 food categories described in the Euromonitor 2011 report.<sup>37</sup> Their review included the systems outlined by Mourbarac et al., the UNC system, as well as a document outlining processing standards by the Food Standards Australian New Zealand (FSANZ).<sup>38</sup> FSANZ classifies foods as unprocessed or processed, using a definition similar to that of the USDA.<sup>38</sup> Two coders classified the 135 food categories using the original frameworks, and processing levels were dichotomized for comparisons.<sup>37</sup> Among systems, agreement in processing assignment ranged from 87% to 99%, with the exception of Nova, whose agreement with other systems ranged from 68% to 81%. To assess ease of applying the frameworks, discrepancies between coders were compared. The Nova system had the highest number of discrepancies (8.1%), attributed to the use of technical definitions and limited example foods, while the UNC system had none, largely due to extensive and detailed food product examples. The authors point out that a major limitation of this analysis was coding food categories, rather than foods.<sup>37</sup> In addition, the analysis did not include an examination of the impact of categorization differences on resulting associations between processing level and nutrient quality of foods.

Of the existing frameworks, the IFIC, UNC and Nova systems have been applied to either U.S. food data or globally, and are therefore most appropriate for further research involving American dietary data. Each classification system employs a unique

coding scheme for foods, with between three and seven processing levels. The Nova and UNC systems assign foods and beverages to four and seven main groups, respectively, according to the extent and purpose of their processing,<sup>39,3</sup> while the IFIC system comprises five levels of processing along a continuum from “minimally processed foods” to “foods packaged for longevity and convenience” (**Table 1**).<sup>40</sup> Both the IFIC and Nova systems include definitions and a short list of example foods for each level of processing. The classification of some foods is subjective, as described by Crino et al.<sup>5,41</sup> The UNC system is presented as an appendix in a paper published by the authors with a detailed classification scheme that categorizes all barcoded foods available in US supermarkets; in the case of homemade or restaurant items, ingredients are classified separately.<sup>3</sup>

While the general language and category assignment between each system is similar, discrepancies are apparent throughout the coding schemes. These differences may lead to varying conclusions regarding the relationship between processed food consumption, dietary quality and health, as well as confusion among consumers regarding an applied definition of processed foods. A direct comparison of these commonly used classification systems, including the effect of framework design on the association between processing level and health outcomes, is necessary to identify discrepancies that significantly impact research.<sup>42</sup>

### **Perceptions and understanding of processed foods**

While the use of processing classification systems in scientific studies has increased dramatically, perceptions and understanding of processing classification applied to foods and healthfulness among non-scientific audiences, particularly children, are largely unknown. The term “processed” is often portrayed as synonymous with “junk food” not only by some health professionals, advocacy organizations and the media, and that may encourage a simplistic view of processing classification.<sup>40</sup> Marketing research in the U.S. demonstrates that consumers are aware of the concept of processed foods, and may have strong beliefs regarding their relationship to health. A 2012 IFIC survey asked shoppers about their perceptions of processed foods.<sup>43</sup> The majority (67%) thought that minimally processed foods were healthful choices, and 59% thought that processed foods can provide affordable, nutritious options, suggesting that adult consumers perceive some

nuances in the relationship between processed foods and healthfulness. However, this survey did not assess consumer definitions of “processed foods.”

In South America, the concept of food processing has recently been adopted to encourage consumers to avoid industrially produced foods and to combat the rapid rise in obesity.<sup>44</sup> Since 2014, The Dietary Guidelines for the Brazilian Population has incorporated processed food guidance into its national report, underlining that “ultra-processed” foods, such as packaged snacks and soft drinks, should be avoided.<sup>45</sup> The Pan American Health Organization published a 2016 report that outlines a nutrient profiling model for processed and ultra-processed products.<sup>44</sup> This model was developed to guide norms and regulations regarding the marketing, front-of-package labeling, and fiscal policies related to processed food sales and distribution in the Americas. However, evidence of the effects of communication and policy efforts aimed at reducing processed food consumption are limited.

One study of college students in Argentina and Ecuador surveyed participants on foods they considered “ultra-processed,” as well as their definition of the term in relation to that of the Nova classification system using a pen and paper survey.<sup>46</sup> Using text and content analysis, results showed that participants associated “ultra-processed” with artificial ingredients, “unnatural” foods, and unhealthful products. Frequently cited foods included milk, meat, culinary ingredients, soft drinks and canned products.<sup>46</sup> While soft drinks and canned products are classified as “ultra-processed” in the Nova system, milk, meat and some ingredients are not.<sup>25</sup> The authors conclude that a clear definition of the term is needed to curb consumption of ultra-processed products.<sup>46</sup> Collecting data from college students was a limitation of this study, since this population may be more highly educated and knowledgeable about health than lower SES populations. In addition, the study did not assess knowledge of other processing levels, including minimally and moderately processed, for comparison. A study of conceptualization of ultra-processing asked Uruguayan adults similar questions via an online survey.<sup>47</sup> Processing technique, added ingredients, and unhealthfulness emerged as characteristics associated with “ultra-processed,” while processed meats, junk food, frozen items and sugar-sweetened beverages (SSBs) were frequently cited examples of ultra-processed foods. Foods commonly misclassified as ultra-processed included milk, meats and flour; these products

were also misclassified by college students in the study discussed above.<sup>46</sup> Both of these studies demonstrate that consumers had a high familiarity with terms used in the Nova system, which may be reflective of widespread adoption of this framework in South America.

Although no such studies on conceptualization of processing have been conducted in the U.S., qualitative studies of children's food perceptions have yielded insight into early predictors of child eating patterns, preferences, and determinants of health. Elliot et al. at the University of Calgary in Canada have conducted extensive research around the subject of child classification of foods, focusing on children's perceptions of "kid food" versus "adult food."<sup>48,49</sup> Results demonstrate that focusing on values underpinning children's classifications, such as "desirable" or "boring," can help to illuminate children's development of food preference. In Ontario, Canada, a project investigating food literacy in disadvantaged youth found that participants perceived cooking with simple ingredients to be healthier, and eating too many "boxed" and fast foods as unhealthy.<sup>50</sup> A study by Cornwell et al. found that children's knowledge of fast food and packaged brands was a significant predictor of BMI, even after considering time spent viewing television.<sup>51</sup> Throughout these studies, the term "processed" was rarely used to talk about foods; however, these results suggest that children employ various classification methods that can influence their perceptions and consumption of foods.

Parents play a key role in determining child eating patterns as the principal household food purchasers and "gatekeepers," and may impact eating behavior through role modelling and socio-cultural factors.<sup>52-54</sup> Research shows consistent associations between parent and child intake of fruits and vegetables,<sup>52</sup> and numerous studies have demonstrated the influence of parent intake on child sugar-sweetened beverage (SSB) consumption.<sup>55</sup> A qualitative study of children's eating habits in Denmark found that children's reported consumption of soda and sweet snacks was generally initiated or supported by parents.<sup>56</sup> These results were similar to findings from a study in Kentucky.<sup>57</sup> As part of an ongoing research project called the Obesogenic Environment Study in São Paulo, Brazil, a qualitative study examined perceptions of barriers and facilitators to ultra-processed food consumption in adults.<sup>58</sup> Notably, child preferences were major facilitators, while health concerns were a barrier to purchasing and consuming ultra-

processed foods.<sup>58</sup> An analysis of data from the Healthy Home Offerings via the Mealtime Environment Plus study found that among parents of children aged 8–12 years, family preferences and lack of time were the main reasons for purchasing processed, prepackaged meals.<sup>59</sup> Additional evidence suggests that parental education level is associated with parent feeding behaviors and child eating habits. Higher parental education is shown to be associated with increased health consciousness in food decisions, and inversely associated with children’s sugar intake and percent of daily energy from fat. Together, these studies suggest that child consumption of both minimally and highly processed foods is substantially affected by parent purchasing and feeding behavior, and that sociodemographic characteristics may impact parent attitudes about food choices.

While the importance of parents in determining child dietary patterns is well-established, involving parents, particularly those from low-SES backgrounds, in nutrition education and interventions is challenging. Barriers to engaging low-income parents include competing time commitments and priorities, unstable schedules and lack of transportation.<sup>60</sup> Nutrition education programs targeting parents have limited impact on improving children’s dietary intake and weight status, in part due to low parent involvement in program activities.<sup>61,62</sup> Low-income immigrant families represent an important target for intervention, as children from this population are at an elevated risk of food insecurity (Hadley) and obesity.<sup>63-66</sup> Dietary acculturation, which describes the changes in dietary practices among immigrants after relocating to the U.S., often results in less healthful dietary patterns including low consumption of fruits and vegetables and consumption of convenience foods.<sup>67</sup> These shifts are due to a number of factors, including busier lifestyles, lack of social support and higher stress levels, as well as children’s requests for American foods.<sup>67</sup> For example, Latino children’s requests for “Americanized” foods were identified as a major influence in family dietary patterns in a systematic review of the relationship between acculturation and diet.<sup>64</sup> Understanding immigrant parents’ attitudes towards and understanding of processed foods is therefore important for improving the diets of children from this population.

In the U.S., no study has systematically examined children’s familiarity with processed food language. Investigating how children think and talk about different foods,

as well as their understanding of processing classification, may offer important insight into policy and communication tactics to encourage healthier eating patterns. Given that parents are responsible for most food selection, preparation and purchasing, exploring parent understanding of processing classification as well as perceptions about processing and health are also important to understanding opportunities to improve child eating habits. Low-income, minority and immigrant parent groups are important targets for research on this topic, as children from these populations are at a higher risk of poor dietary habits and associated disease risk.

### **Processed food consumption and weight status**

Extensive evidence links high consumption of SSBs,<sup>68</sup> low consumption of whole grains,<sup>69</sup> and diets low in fiber to excess weight in children.<sup>70</sup> However, whether processing is an independent contributor to childhood obesity remains unclear. Researchers hypothesize that HPF consumption impacts body weight by increasing added sugars, fats and total calorie intake, and displacing foods high in fiber, protein and micronutrients.<sup>22,24,71</sup> Others have posited that convenience is a key factor in promoting excess caloric intake.<sup>3,72</sup> Further evidence suggests that hyper-palatable processed foods, which achieve sensory appeal through the addition of salt, sugar, flavors or additives, have addictive potential,<sup>19,73,74</sup> to which children are particularly vulnerable.<sup>75,76</sup>

Several cross-sectional studies conducted globally using the Nova system support an association between consumption of HPFs and obesity among adults and children.<sup>21,26,77-79</sup> In a review of 26 articles examining the association between HPF intake and body fatness in children, results were mixed, with more than half of studies showing a positive association.<sup>42</sup> The authors stress that none of the studies investigated whether total energy intake mediated the effect of consumption of HPFs and body fatness, and data collection measures varied widely among studies.

Further evidence points to an association between highly processed food intake, cardiovascular disease<sup>70,80,81</sup> and metabolic syndrome in children,<sup>82</sup> conditions that are often associated with obesity. Related research has examined associations between specific food groups considered to be HPFs, finding positive associations between sugar-sweetened beverages,<sup>68,83</sup> a Western dietary pattern and excess body weight.<sup>84</sup> However, scholars note that there is limited research investigating each of these outcomes, and the

majority of studies are cross-sectional in design.<sup>85</sup> One prospective study of HPF consumption and risk of overweight and obesity in a middle-aged Spanish cohort found that the highest HPF consumers were at a greater risk of overweight and obesity.<sup>71</sup> This study was limited by use of a food frequency questionnaire that asked about 136 commonly-consumed HPFs, rather than a measure of total diet, and a study sample consisting of university graduates that may not be generalizable to other populations.

A recent (and yet unpublished) randomized controlled trial of ultra-processed diets in an inpatient setting demonstrated an average weight gain of  $0.8 \pm 0.3$  kg during two weeks of ad libitum consumption of an “ultra-processed” diet, and an average weight loss of  $1.1 \pm 0.3$  kg during consumption of an unprocessed diet among overweight adults enrolled in the study.<sup>86</sup> Participants were presented with meals and snacks of similar energy density and nutrient concentration in both diet phases. Energy intake increased by  $508 \pm 106$  kcal/day on average during the ultra-processed diet, resulting from increased intake of carbohydrates and fat, but not protein. Of note, sodium intake was significantly increased during the ultra-processed phase, but added sugars and fiber stayed constant. The study had several notable limitations, including use of a fiber-supplemented beverage in the ultra-processed phase, which may not effect satiety in the same way as fiber rich foods. The authors point out that the unprocessed diet may require considerable more time and resources to prepare, and thus may not be generalizable to real life situations. However, as the first randomized controlled trail of ultra-processed food intake, these results provide further context on possible links between processing and weigh status.

In contrast, an analysis of fast food consumption among 2–18 year olds included in NHANES, published by the authors of the UNC classification system, found that fast food (considered HPF) consumption was not independently associated with overweight or obesity.<sup>84</sup> A study of adults in the United Kingdom found an inverse association between overall intake of “processed culinary ingredients” (such as sugars and oils) and body weight, but no association specifically with intake of HPFs.<sup>79</sup> Similarly, a longitudinal analysis of 1,035 adolescents from Brazil found that those in the top quartile of HPF consumption had lower intake of fruits and vegetables, as well as a lower body mass index (BMI) at baseline and follow-up.<sup>87</sup> Children in the top quartile of HPF consumption also had higher physical activity levels, which may help to explain these

unexpected relationships.<sup>87</sup> The authors suggest that obesity may be more closely related to quantity rather than quality of foods consumed; this hypothesis is supported by interventions that found no change in obesity when high energy-dense foods are displaced by fruits and vegetables.<sup>88,89</sup>

### **Processed food consumption and diet quality**

In an effort to further elucidate the relationship between processed food consumption and weight status, several studies have evaluated the nutritional contributions of highly processed products to food purchases and dietary intake. Extensive evidence demonstrates that children from lower socio-economic status backgrounds have lower diet quality, which may increase the risk of adverse health outcomes during childhood or later in life.<sup>15,16,90</sup> A study of national food purchase data from 2000–2012 in the U.S. found that households were more likely to exceed recommendations for saturated fat, sugar and salt intake for HPF compared to less-processed food purchases,<sup>3</sup> while an analysis of NHANES dietary recalls showed an association between HPF and consumption of added sugars.<sup>7</sup> Evidence from Colombia<sup>91</sup> and Brazil<sup>92</sup> has demonstrated lower nutritional profiles among children and young adults, respectively, who ate higher amounts of HPFs. Using national food consumption data, a more recent study from Brazil showed a direct association between highly processed food consumption and an unhealthful dietary pattern.<sup>93</sup>

In contrast, an analysis of 2–18 year olds in NHANES 2003–2008 concluded that all categories of processed foods contributed vitamins, minerals and macronutrients to the diets of children, and that advising selection of foods based on energy and nutrient composition, rather than processing level, was prudent.<sup>30</sup> Whereas highly processed, fortified foods may be particularly important sources of nutrients for children from low SES backgrounds, it remains unknown how these foods affect overall diet quality. This study used the IFIC system to classify foods, which indicates that the classification system used may influence study results. Furthermore, this evidence suggests that IFIC system may lead to more conservative estimates of the impact of processing on dietary quality compared to other systems.

**Summary**

The use of frameworks for classifying foods according to processing level in research has increased dramatically over the past decade. Lack of a universal system for classifying processed foods leads to inconsistent findings in studies of their effects on health, and potential for subjectivity in application of these frameworks suggests that conclusions stemming from their use may be biased. A rigorous evaluation of these systems in the context of the U.S. consumption habits is needed. Further, these studies suggest that processing classification frameworks may be useful for promoting healthful eating among vulnerable populations. However, there is a lack of understanding of how consumers perceive processed foods, which then impacts the ability of health communicators to provide guidance on their consumption. In particular, research is needed to better understand how low-income and minority children and their parents, who are at a greater risk of having poor dietary quality and developing overweight and obesity, perceive processed foods and their relationship to healthfulness.

## REFERENCES

1. Wrangham R. *Catching fire: how cooking made us human*. New York;2009.
2. Chapter 9—Federal Food, Drug, and Cosmetic Act. In. *Title 21—Food and Drugs*. Vol 21: US Food and Drug Administration, Department of Health and Human Services; 2016.
3. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.
4. Carlos Augusto Monteiro RBL, Rafael Moreira Claro, Inês Rugani Ribeiro de Castro, Geoffrey Cannon A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11).
5. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003-2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S-2072S.
6. Floros JD, Newsome R. Feeding the World Today and Tomorrow: The Importance of Food Science and Technology: An IFT Scientific Review. *Comprehensive Reviews in Food Science and Food Safety*. 2010;0.
7. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2016;6(3):e009892.
8. Whitaker RC, Wright JA, Pepe M, Seidel K, Dietz W. Predicting obesity in young adulthood from childhood and parental obesity. *The New England Journal of Medicine*. 1997;337(13).
9. Golley RK, Smithers LG, Mittinty MN, Emmett P, Northstone K, Lynch JW. Diet quality of U.K. infants is associated with dietary, adiposity, cardiovascular, and cognitive outcomes measured at 7-8 years of age. *J Nutr*. 2013;143(10):1611-1617.
10. Anderson M, Butcher F. Childhood Obesity: Trends and Potential Causes. *The Future of Children*. 2006;16(1):19-45.
11. Hales C, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2017;288.
12. Wang Y, Beydoun MA. The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev*. 2007;29:6-28.
13. Ogden CL, Carroll MD, Fakhouri TH, et al. Prevalence of Obesity Among Youths by Household Income and Education Level of Head of Household — United States 2011–2014. *MMWR Morb Mortal Wkly Rep* 2018;67:186–189.
14. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med*. 2009;36(1):74-81.

15. Ranjit N, Wilkinson AV, Lytle LM, Evans AE, Saxton D, Hoelscher DM. Socioeconomic inequalities in children's diet: the role of the home food environment. *Int J Behav Nutr Phys Act*. 2015;12 Suppl 1:S4.
16. Fahlman MM, McCaughy N, Martin J, Shen B. Racial and socioeconomic disparities in nutrition behaviors: targeted interventions needed. *J Nutr Educ Behav*. 2010;42(1):10-16.
17. Mozaffarian D, Ludwig D. Dietary Guidelines in the 21st Century— a Time for Food. *JAMA*. 2010;304(6):681-682.
18. Brunner TA, van der Horst K, Siegrist M. Convenience food products. Drivers for consumption. *Appetite*. 2010;55(3):498-506.
19. Gearhardt AN, Grilo CM, DiLeone RJ, Brownell KD, Potenza MN. Can food be addictive? Public health and policy implications. *Addiction*. 2011;106(7):1208-1212.
20. Moodie DS, Monteiro C, Sheron N, Neal B, Thamarangsi T, Lincoln P, Casswell S. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet*. 2013;381:670-679.
21. Louzada ML, Baraldi LG, Steele EM, et al. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med*. 2015;81:9-15.
22. Fardet A, Rock E, Bassama J, et al. Current food classifications in epidemiological studies do not enable solid nutritional recommendations for preventing diet-related chronic diseases: the impact of food processing. *Adv Nutr*. 2015;6(6):629-638.
23. Fardet A. Minimally processed foods are more satiating and less hyperglycemic than ultra-processed foods: a preliminary study with 98 ready-to-eat foods. *Food Funct*. 2016;7(5):2338-2346.
24. Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutr*. 2009;12(5):729-731.
25. Moubarac JC, Parra DC, Cannon G, Monteiro CA. Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. *Curr Obes Rep*. 2014;3(2):256-272.
26. Asfaw A. Does consumption of processed foods explain disparities in the body weight of individuals? The case of Guatemala. *Health Econ*. 2011;20(2):184-195.
27. González-Castell D, González-Cossío T, Barquera S, Rivera J. Contribution of processed foods to the energy, macronutrient and fiber intakes of Mexican children aged 1 to 4 years. *Salud Publica Mex*. 2007;49(5):345–356.
28. Slimani N, Deharveng G, Southgate DA, et al. Contribution of highly industrially processed foods to the nutrient intakes and patterns of middle-aged populations in the European Prospective Investigation into Cancer and Nutrition study. *Eur J Clin Nutr*. 2009;63 Suppl 4:S206-225.
29. Chajes V, Biessy C, Byrnes G, et al. Ecological-level associations between highly processed food intakes and plasma phospholipid elaidic acid concentrations: results from a cross-sectional study within the European prospective investigation into cancer and nutrition (EPIC). *Nutr Cancer*. 2011;63(8):1235-1250.

30. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients*. 2015;7(12):10076-10088.
31. Luiten CM, Steenhuis IH, Eyles H, Ni Mhurchu C, Waterlander WE. Ultra-processed foods have the worst nutrient profile, yet they are the most available packaged products in a sample of New Zealand supermarkets. *Public Health Nutr*. 2016;19(3):530-538.
32. Marron-Ponce JA, Sanchez-Pimienta TG, Louzada M, Batis C. Energy contribution of NOVA food groups and sociodemographic determinants of ultra-processed food consumption in the Mexican population. *Public Health Nutr*. 2017:1-8.
33. Nasreddine L, Tamim H, Itani L, et al. A minimally processed dietary pattern is associated with lower odds of metabolic syndrome among Lebanese adults. *Public Health Nutr*. 2017:1-12.
34. O'Halloran SA, Lacy KE, Grimes CA, Woods J, Campbell KJ, Nowson CA. A novel processed food classification system applied to Australian food composition databases. *J Hum Nutr Diet*. 2017.
35. Moubarac JC, Martins AP, Claro RM, Levy RB, Cannon G, Monteiro CA. Consumption of ultra-processed foods and likely impact on human health. Evidence from Canada. *Public Health Nutr*. 2013;16(12):2240-2248.
36. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly Processed and Ready-to-Eat Packaged Food and Beverage Purchases Differ by Race/Ethnicity among US Households. *J Nutr*. 2016;146(9):1722-1730.
37. Crino M, Barakat T, Trevena H, Neal B. Systematic Review and Comparison of Classification Frameworks Describing the Degree of Food Processing. *Nutrition and Food Technology: Open Access*. 2017;3(1).
38. Food Standards Australia New Zealand. Australia New Zealand Food Standards Code - Standard 3.2.2 - Food Safety Practices and General Requirements 2014. Accessed March 1, 2019.
39. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. *Obes Rev*. 2013;14 Suppl 2:21-28.
40. Dwyer JT, Fulgoni VL, 3rd, Clemens RA, Schmidt DB, Freedman MR. Is "processed" a four-letter word? The role of processed foods in achieving dietary guidelines and nutrient recommendations. *Adv Nutr*. 2012;3(4):536-548.
41. Monteiro C, Levy RB, Claro RM, Ribeiro de Castro IR, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11):2039-2049.
42. Costa CS, Del-Ponte B, Assuncao MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr*. 2017:1-12.
43. 2012 Food and Health Survey: consumer attitudes toward food safety, nutrition and health. Washington, D.C.2012.
44. Pan American Health Organization Nutrient Profile Model. Washington, DC: PAHO;2016.

45. Ministry of Health Brazil. Dietary Guidelines for the Brazilian Population, 2nd edition. 2014.
46. Aguirre A, Borneo MT, El Khor S, Borneo R. Exploring the understanding of the term "ultra-processed foods" by young consumers. *Food Res Int*. 2019;115:535-540.
47. Ares G, Vidal L, Allegue G, et al. Consumers' conceptualization of ultra-processed foods. *Appetite*. 2016;105:611-617.
48. Elliott C. Eatertainment and the (Re)classification of Children's Foods. *Food, Culture and Society: An International Journal of Multidisciplinary Research*. 2010;13(4):539-553.
49. Elliott C. "It's junk food and chicken nuggets": Children's perspectives on 'kids' food' and the question of food classification. *Journal of Consumer Behaviour*. 2011;10(3):133-140.
50. Desjardins E. *"Making something out of nothing": Food literacy among youth, young pregnant women and young parents who are at risk for poor health*. Ontario, Canada: Public Health Ontario;2013.
51. Cornwell TB, McAlister AR, Polmear-Swendris N. Children's knowledge of packaged and fast food brands and their BMI. Why the relationship matters for policy makers. *Appetite*. 2014;81:277-283.
52. van der Horst K, Oenema A, Ferreira I, et al. A systematic review of environmental correlates of obesity-related dietary behaviors in youth. *Health Educ Res*. 2007;22(2):203-226.
53. Wang L, Dalton WT, Schetzina KE, et al. Home Food Environment, Dietary Intake, and Weight among Overweight and Obese Children in Southern Appalachia. *Southern Medical Journal*. 2013;106(10):550-557.
54. Adamo KB, Brett KE. Parental perceptions and childhood dietary quality. *Matern Child Health J*. 2014;18(4):978-995.
55. Yee AZ, Lwin MO, Ho SS. The influence of parental practices on child promotive and preventive food consumption behaviors: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):47.
56. Husby I, Heitmann BL, O'Doherty Jensen K. Meals and snacks from the child's perspective: the contribution of qualitative methods to the development of dietary interventions. *Public Health Nutr*. 2009;12(6):739-747.
57. Roos G. Our bodies are made of pizza--food and embodiment among children in Kentucky. *Ecology of Food and Nutrition*. 2002;41(1):1-19.
58. Almeida LB, Scagliusi FB, Duran AC, Jaime PC. Barriers to and facilitators of ultra-processed food consumption: perceptions of Brazilian adults. *Public Health Nutr*. 2017:1-9.
59. Horning ML, Fulkerson JA, Friend SE, Story M. Reasons Parents Buy Prepackaged, Processed Meals: It Is More Complicated Than "I Don't Have Time". *J Nutr Educ Behav*. 2017;49(1):60-66 e61.
60. Winslow E, Bonds D, S W. Predictors of enrollment and retention in a preventive parenting intervention for divorced families. *J Prim Prev*. 2009;30:151-172.
61. Ciampa P, Kumar D, SL B. Interventions aimed at decreasing obesity in children younger than 2 years: a systematic review. *Arch Pediatr Adolesc Med*. 2010;164:1098-1104.

62. Prinz R, Smith E, Dumas J, Laughlin J, White D, Barrón R. Recruitment and retention of participants in prevention trials involving family-based interventions. *Am J Prev Med.* 2001;20:31-37.
63. Popkin B, Urdy J. Adolescent Obesity Increases Significantly in Second and Third Generation U.S. Immigrants: The National Longitudinal Study of Adolescent Health. *J Nutr.* 1998;128(4):701-706.
64. Ayala GX, Baquero B, Klinger S. A systematic review of the relationship between acculturation and diet among Latinos in the United States: implications for future research. *J Am Diet Assoc.* 2008;108(8):1330-1344.
65. Oza-Frank R, Cunningham SA. The weight of US residence among immigrants: a systematic review. *Obes Rev.* 2010;11(4):271-280.
66. Goel M, McCarthy E, Phillips R, Wee C. Obesity among US immigrant subgroups by duration of residence. *JAMA.* 2004;292(23):2860-2867.
67. Popovic-Lipovac A, Strasser B. A review on changes in food habits among immigrant women and implications for health. *J Immigr Minor Health.* 17(2):582-590.
68. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *The American Journal of Clinical Nutrition.* 2013;98(4):1084-1102.
69. Zanovec M, O'Neil CE, Cho SS, Kleinman RE, Nicklas TA. Relationship between whole grain and fiber consumption and body weight measures among 6- to 18-year-olds. *J Pediatr.* 2010;157(4):578-583.
70. Appannah G, Pot GK, Huang RC, et al. Identification of a dietary pattern associated with greater cardiometabolic risk in adolescence. *Nutr Metab Cardiovasc Dis.* 2015;25(7):643-650.
71. Mendonca RD, Pimenta AM, Gea A, et al. Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr.* 2016;104(5):1433-1440.
72. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada ML, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr.* 2017;1-13.
73. Volkow ND, Wang GJ, Fowler JS, Telang F. Overlapping neuronal circuits in addiction and obesity: evidence of systems pathology. *Philos Trans R Soc Lond B Biol Sci.* 2008;363(1507):3191-3200.
74. Avena NM, Rada P, Hoebel BG. Evidence for sugar addiction: Behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neurosci Biobehav Rev.* 2008;32(1):20-39.
75. Gearhardt AN, Roberto CA, Seaman MJ, Corbin WR, Brownell KD. Preliminary validation of the Yale Food Addiction Scale for children. *Eat Behav.* 2013;14(4):508-512.
76. Gearhardt A, Davis C, Kuschner R, Brownell K. The Addiction Potential of Hyperpalatable Foods. *Current Drug Abuse Reviews.* 2011;4:140-145.
77. Canella DS, Levy RB, Martins AP, et al. Ultra-processed food products and obesity in Brazilian households (2008-2009). *PloS one.* 2014;9(3):e92752.

78. Juul F, Hemmingsson E. Trends in consumption of ultra-processed foods and obesity in Sweden between 1960 and 2010. *Public Health Nutr.* 2015;18(17):3096-3107.
79. Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *Int J Behav Nutr Phys Act.* 2015;12:160.
80. Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. *Nutr Metab Cardiovasc Dis.* 2015;25(1):116-122.
81. Vitolo MR, Rauber F. Influence of Food Processing on Blood Lipids in Children. *Nutrients.* 2016;8(2):97.
82. Tavares LF, Fonseca SC, Garcia Rosa ML, Yokoo EM. Relationship between ultra-processed foods and metabolic syndrome in adolescents from a Brazilian Family Doctor Program. *Public Health Nutr.* 2012;15(1):82-87.
83. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA. Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Pediatrics.* 2013;131(1):14-21.
84. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? *Am J Clin Nutr.* 2014;99(1):162-171.
85. Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? *Curr Obes Rep.* 2017;6(4):420-431.
86. Hall K, Ayuketah A, Bernstein S, et al. Ultra-processed diets cause excess calorie intake and weight gain: A one-month inpatient randomized controlled trial of ad libitum food intake. *Under Review.* 2019.
87. Cunha DB, da Costa THM, da Veiga GV, Pereira RA, Sichieri R. Ultra-processed food consumption and adiposity trajectories in a Brazilian cohort of adolescents: ELANA study. *Nutr Diabetes.* 2018;8(1):28.
88. Kaiser KA, Brown AW, Bohan Brown MM, Shikany JM, Mattes RD, Allison DB. Increased fruit and vegetable intake has no discernible effect on weight loss: a systematic review and meta-analysis. *Am J Clin Nutr.* 2014;100(2):567-576.
89. Bayer O, Nehring I, Bolte G, von Kries R. Fruit and vegetable consumption and BMI change in primary school-age children: a cohort study. *Eur J Clin Nutr.* 2014;68(2):265-270.
90. Kirkpatrick SI, Dodd KW, Reedy J, Krebs-Smith SM. Income and race/ethnicity are associated with adherence to food-based dietary guidance among US adults and children. *J Acad Nutr Diet.* 2012;112(5):624-635 e626.
91. Cornwell B, Villamor E, Mora-Plazas M, Marin C, Monteiro CA, Baylin A. Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. *Public Health Nutr.* 2017:1-6.
92. Bielemann RM, Motta JVS, Minten GC, Horta BL, Gigante DP. Consumption of ultra-processed foods and their impact on the diet of young adults. *Revista de Saúde Pública.* 2015;49(0).

93. Louzada M, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr.* 2017;1-9.

## CHAPTER III: Alignment of food processing classification systems with nutrient quality

### Authors

Rachel Bleiweiss-Sande, MS<sup>1</sup>; Kenneth Chui, PhD, MPH<sup>1</sup>; Erin Whitney Evans, PhD, RD<sup>2</sup>; Jeanne Goldberg, PhD, RD<sup>1</sup> and Jennifer Sacheck, PhD<sup>3</sup>

<sup>1</sup>Friedman School of Nutrition Science and Policy, Tufts University

<sup>2</sup>Warren Alpert Medical School, Brown University

<sup>3</sup>Milken Institute School of Public Health, The George Washington University

### ABSTRACT

*Background.* Dietary patterns characterized by energy-dense, highly-processed foods may be a contributing factor to lower dietary quality and related health outcomes, particularly among disadvantaged children. However, discrepancies between food processing classification systems have led to varying conclusions regarding the relationship between intake, dietary quality and health outcomes in youth.

*Objectives:* This study sought to examine (a) the reliability of processing level within and between three food processing classification systems, and (b) the relationship between processing level and nutrient concentration as predicted by each classification system.

*Methods.* The Nova system, International Food Information Council (IFIC) system, and a system developed by researchers at the University of North Carolina at Chapel Hill (UNC) were used. Two PhD-level dietitians independently coded processing level according to each system for the top 100 most commonly consumed foods among children 6–12 years old who participated in the 2013-2014 National Health and Nutrition Examination Survey. Processing level assignment was compared using Spearman's rank correlation coefficient. Concentration of under- and over-consumed nutrients as specified by the Dietary Guidelines for Americans was quantified for a standard serving of each food. Relative ability of processing classification systems to predict nutrient concentration was investigated using linear discriminant analysis and multinomial logistic regression and compared between systems using Cohen's kappa coefficient.

*Results.* The Nova system classified more of the 100 foods as highly processed (70%) compared to the IFIC (53%) and UNC (62%) systems. The UNC system had the highest inter-rater reliability ( $\rho = 0.97$ ), followed by IFIC ( $\rho = 0.78$ ) and Nova ( $\rho = 0.76$ ). UNC and Nova systems had the highest agreement (80%); Nova and IFIC had the lowest (73%). Lower potassium was a significant predictor of moderately compared to minimally processed foods for the IFIC system ( $p = 0.01$ ), and lower vitamin D was predictive of highly compared to minimally processed foods for the UNC system ( $p = 0.04$ ). Greater sodium and added sugars was significantly predictive of high processing level compared to minimal for all three systems ( $p < 0.05$ ).

*Conclusions.* Universal definitions for processing level assignment are needed to ensure consistent methodology and comparable results in studies examining the relationship between processed food intake, nutrient quality, and health. Current processing classification systems may not be sufficient to identify foods with high nutrient quality among children in the U.S.

## BACKGROUND

The prevalence of childhood overweight and obesity remains elevated in the United States (U.S.), particularly in lower-income and minority populations.<sup>1-4</sup> It is widely accepted that poor diet is a key contributor to caloric imbalances and weight status in children. Over the past decades, researchers have documented eating pattern shifts that favor sweetened beverages over water and milk<sup>5</sup>; takeaway food over meals eaten at home,<sup>6</sup> and snacking over traditional meal patterns,<sup>7</sup> collectively referred to as the nutrition transition.<sup>8</sup> Modern industrial food processing is a common denominator driving these dietary shifts. Accordingly, processed foods have been advanced as a potential driver of the child obesity epidemic, but their role in terms of nutrition and health in modern day diets is currently under debate.<sup>9</sup>

Food processing, in forms such as cooking, fermenting and salt-preservation, has been an integral part of human diets for over two-million years.<sup>10,11</sup> However, modern food processing techniques, which were introduced during the industrial revolution and take place on a mass scale, are relatively new.<sup>10</sup> The U.S. Department of Agriculture (USDA), defines food processing as any procedure that alters food from its natural state.<sup>12</sup> Thus, any food aside from raw, agricultural commodities is considered processed. Because of the considerable heterogeneity across industrially processed foods, researchers have developed classification systems to distinguish foods according to the level or complexity of processing, ranging from minimally to highly processed.<sup>13-15</sup>

Several systems have been applied to either U.S. food data or globally, and are therefore most appropriate for further research involving American dietary data. These include the Nova system, developed in Brazil and used internationally in research<sup>14</sup>; a system developed by the International Food Information Council (IFIC) and used to examine the nutrient quality of foods consumed by Americans by processing category,<sup>15,16</sup> and one by researchers at the University of North Carolina at Chapel Hill (UNC) that classifies all barcoded foods items sold in U.S. supermarkets.<sup>13</sup>

Discrepancies between these classification systems have resulted in varying conclusions regarding the relationship between processed food consumption and dietary quality. For example, an analysis of NHANES 2009-2010 data using the Nova system found that added sugar in foods from the highest processing level (ultra-processed) was

eightfold higher than foods in the next highest processing level (processed).<sup>17</sup> Similarly, a study using the UNC system found that households were significantly more likely to exceed maximum daily recommendations of saturated fat, sugar, and sodium content with highly compared to less-processed food purchases.<sup>13</sup> In contrast, a study using the IFIC system demonstrated that processing level is a minor determinant of nutrient contributions in the diet.<sup>15</sup>

Proponents of processing level classification argue that traditional food classifications, such as nutrient density and food groups, fail to distinguish between unaltered and reformulated versions of a food, potentially leading to misclassification of healthful products.<sup>18</sup> In addition, by translating nutrient-based targets into food-based recommendations, dietary guidelines may encourage extreme levels of fortification by the food industry to portray highly processed foods as nutritious.<sup>19</sup> However, without universally accepted definitions of processing levels and consistent category assignment, it is impossible to compare results across studies. A direct comparison of these classification systems is necessary to avoid further misunderstandings and potential misclassification of foods in future research.<sup>20</sup> The objectives of this study were to 1) investigate the inter-rater reliability of three food processing classification systems and 2) examine the relationship between processing level and nutrient concentration as predicted by each classification system, using the top 100 most commonly consumed foods by children in the U.S.

## METHODS

*Sample size and data source.* Since an overarching aim of this research was to evaluate whether processing level is a useful measure of healthfulness in children's diets, we determined the 100 most commonly foods consumed by children, ages six to twelve years old, who participated in the National Health and Nutrition Examination Survey (NHANES) 2013-2014.<sup>21</sup> For validation or reliability studies estimating agreement between two different variables, a sample size of 100 gives very good precision, while 60-70 observations is generally accepted as adequate.<sup>22</sup> All participants in the 2013-2014 cycle were asked to complete two, 24-hour recall dietary interviews, conducted using the USDA Multiple-Pass Method (AMPM) by trained interviewers.<sup>23</sup> For children under nine

years old, the interview was conducted with a proxy who was knowledgeable about the child's consumption the day before the interview. For children 9-11 years old, the child provided their own data with an adult household member present.<sup>23</sup> For this study, we analyzed food records from children who completed both days of dietary recalls and had no missing demographic data.

The top 100 foods were identified according to total reported servings consumed by children ages six to twelve years. Servings, rather than count, volume or weight, was chosen to avoid biasing the sample toward foods eaten often but in small servings, low-weight foods with added volume (such as puffed snacks) and very heavy foods (beverages and soups). To determine servings, foods from the NHANES dataset were merged with the Food and Nutrient Database for Dietary Studies (FNDDS) 2013-2014 portions and weights database by Standard Reference (SR) code.<sup>24</sup> The FNDDS is used to convert foods and beverages from NHANES into gram amounts, including portion weights, and to determine their nutrient values.<sup>24</sup> Because the portions and weights database lists multiple portion sizes and associated gram weights for each food (for example, 1 tablespoon of cereal, ½ cup of cereal, 1 container of cereal), duplicate portion size entries were removed, and remaining portion size entries were compared to standard serving sizes published in the United States Department of Agriculture (USDA) Nutrient Reference Database to ensure accuracy.<sup>25</sup>

To allow for an analysis based on the nutrient-density of foods according to their processing level, the most commonly under- and over-consumed nutrients in the U.S. were identified according to the Dietary Guidelines for Americans (DGA).<sup>26</sup> Under-consumed nutrients include potassium, fiber, choline, magnesium, calcium, iron, and vitamins A, D, E, and C. Over-consumed nutrients include added sugars, saturated fat and sodium.<sup>26</sup> Association between energy density and processing level was also explored. The FNDDS nutrient values database was used to determine nutrient values for a standardized amount (100 grams) of each food and multiplied by serving size to determine nutrient concentration per serving.<sup>25</sup> Amount of added sugars was obtained from the Food Patterns Equivalents Database 2013-2014.<sup>25</sup>

*Processing classification systems.* Food processing classification systems applied to North American food purchase or consumption datasets, referenced in published

scientific literature, were used in analyses. Three systems meet these criteria, based on a systematic review by Moubarac et al.<sup>27</sup> and further literature review by the authors. The systems include Nova, developed by researchers at the Centre for Epidemiological Studies in Health and Nutrition at the School of Public Health, University of São Paulo;<sup>28</sup> a system developed by researchers at UNC for barcoded food items in the U.S.,<sup>13</sup> and a system devised by the IFIC.<sup>29</sup> The UNC system is based on the Nova system, but modified to capture the complexity of the U.S. food supply with enhanced category definitions and examples.<sup>13</sup> Details of each system are presented in **Table 1**.

*Processing classification level assignment.* Two PhD-level registered dietitians independently coded the top 100 foods by processing level using each system. Coders were instructed to follow guidelines from published documents outlining system classification criteria.<sup>13,27,29</sup> Published studies employing the systems were used to clarify application of the processing system.<sup>15,17,30,31</sup> In cases of ambiguity, coders were instructed to choose the more conservative processing level (i.e., less processed). For the IFIC and Nova systems, foods are classified into five and four levels, respectively, as presented in **Table 1**.<sup>27,29</sup> The UNC system utilizes the same scheme as Nova, but further subdivides foods into seven processing levels (unprocessed/minimally, basic – preservation, basic – ingredient, moderately – grain product, moderately – flavor, highly – ingredient and highly).<sup>13</sup> To examine inter-rater reliability, original processing level assignment was compared between coders (level 1-5 for IFIC; level 1-4 for Nova, level 1-7 for UNC).

A third coder (author 1) evaluated coding discrepancies, and determined a final coding decision for each food for use in analyses examining the relationship between processing level and nutrient concentration. In order to compare systems on a common scale, processing classifications were collapsed to four levels: for IFIC, levels four (ready-to-eat processed) and five (prepared foods/meals) were combined into level four. For UNC, levels two (basic – preservation) and three (basic – ingredient) were combined into level two; levels four (moderately – grain product) and five (moderately – flavor) were combined into level three, and levels six (highly – ingredient) and seven (highly) were combined into level four. Due to insufficient numbers of level two foods, levels one and two were combined for all systems. Other studies have found small proportions of

foods classified as basic/processed for preservation compared to other levels, supporting the decision to combine this category with level one.<sup>15,31,32</sup> The resulting categories were level one (unprocessed/minimally), level two (moderately processed) and level three (highly processed) (**Figure 1**).

*Analysis.* All statistical analyses were performed using Stata version 15 (StataCorp; College Station, TX). For objective 1, Spearman's rank correlation coefficient was used to quantify inter-rater reliability of processing level assignment between coders. Relative ability of processing classification systems to predict nutrient concentration was compared using Cohen's kappa coefficient. Because the outcome of interest was agreement between processing systems, four-level processing ratings were used for comparison. Agreement was defined according guidelines published by Landis and Koch, where 0.00 – 0.20 is slight agreement; 0.21 – 0.40 is fair; 0.41 – 0.60 is moderate; 0.61 – 0.80 is substantial, and 0.81 – 1.00 is almost perfect.<sup>33</sup> For objective two, we used two analysis methods to investigate the relationship between processing classification and nutrient concentration. First, discriminant function analysis was used to allow for visual exploration of the ability of processing classification systems to distinguish foods by nutrient concentration. Next, the relationship was described further using multinomial logistic regression. Both procedures are multivariate and provide information on individual dimensions, but offer different insight through post-estimation commands and visualization.

We considered *p* values of less than 0.05 to be statistically significant.

## RESULTS

The top five most commonly consumed foods by servings per day were 2% reduced fat milk, white bread, “tomato catsup” (ketchup), American cheese and whole milk. The majority of the top 100 most commonly consumed foods were classified as highly processed, regardless of classification system used. However, the Nova system classified the most foods as highly processed (70%) compared to the UNC (62%) and IFIC (53%) systems. Appendix 1 lists all foods and processing level assignment, including common and discrepant classifications between systems.

*Inter-rater reliability.* Agreement between coders for processing level within classification systems was high for the UNC system ( $\rho = 0.97$ ,  $p < 0.001$ ), and lower for the IFIC ( $\rho = 0.78$ ,  $p < 0.001$ ) and Nova ( $\rho = 0.76$ ,  $p < 0.001$ ) systems.

*Processing system agreement.* Overall agreement between classification systems was moderate for all comparisons ( $0.41 < \text{kappa} < 0.60$ ). The Nova and IFIC systems had 70.0% agreement (expected agreement = 42.1;  $\text{kappa} = 0.48$ ;  $p < 0.0001$ ). Agreement was slightly higher for the Nova and UNC systems at 76.0% (expected agreement = 47.3;  $\text{kappa} = 0.54$ ;  $p < 0.0001$ ) and the IFIC and UNC systems at 75.0% (expected agreement = 39.2;  $\text{kappa} = 0.59$ ;  $p < 0.0001$ ). See Appendix A.1 for commonly classified foods and disagreements between systems.

*Relationship between processing level and nutrient concentration.* Mean nutrient concentrations by processing level for the IFIC, Nova and UNC systems are presented in **Table 2**.

**Figure 2** depicts the relationships between the ability of each classification system to differentiate nutrient concentrations among the top 100 foods. These scatterplots display these foods as defined by the linear discriminate functions when nutrient concentrations are considered for discrimination. For the IFIC system, 77.8% of minimally processed foods were correctly classified, 48.3% of moderately processed foods were correctly classified, and 90.6% of highly processed foods were correctly classified. The first linear discriminate explained 79.8% of the between group variance, and the second discriminate explained 20.2%. For the Nova system, 61.9% of minimally processed foods were correctly classified, 33.3% of moderately processed foods were correctly classified, and 95.7% of highly processed foods were correctly classified; the first discriminant function explained 71.6% of variability. Finally, 54.2% of minimally processed foods were correctly classified for the UNC system, 57.1% of moderately processed foods were correctly classified, and 90.3% of highly processed foods were correctly classified. The first discriminant function explained 76.3% of variability for the UNC system.

The results of multinomial logistic regression models of the association between classification level and nutrients of concern among the top 100 foods are presented in table 2. Of the over-consumed nutrients, higher added sugar was a significant predictor of

moderately compared to minimally processed foods for the UNC system, and highly compared to minimally processed foods for all systems. Higher sodium was a significant predictor of moderately compared to minimally processed foods for Nova, and highly compared to minimally processed foods for all three systems. Of the under-consumed nutrients, lower potassium was a significant predictor of moderately processed compared to minimally processed foods for the IFIC system (RRR = 0.97,  $p = 0.01$ , 95% CI [0.94, 0.99]). Lower vitamin D was a significant predictor of highly compared to minimally processed foods for the UNC system (RRR = 0.06,  $p = 0.04$ , 95% CI [0.00, 0.83]). Given that a high number of foods contained listed value of zero for several nutrients, we removed five nutrients from the model: choline, magnesium, and vitamins A, E and C. As specified by the DGA, these nutrients are consumed in amounts below the Estimated Average Requirement or Adequate Intake levels, but are not considered nutrients of public health concern because low intakes are not associated with health concerns.<sup>26</sup>

## DISCUSSION

As use of the term “processed” increases among researchers and the general public, there is a need for a universally accepted classification system and common definitions to describe processing levels.<sup>34,35</sup> In the U.S., processed food consumption has been examined with regard to racial/ethnic disparities<sup>16,31</sup>, dietary quality<sup>30</sup>, obesity<sup>36</sup>, body fat<sup>20</sup> and weight gain<sup>37</sup>, while globally researchers have examined associations with obesity<sup>38,39</sup>, lipid profiles<sup>40</sup>, metabolic syndrome<sup>41</sup>, cancer risk<sup>42</sup> and mortality among others. These investigations have reached disparate conclusions, which may depend on the processing classification system used in analyses. Understanding the effects of processed food consumption during childhood may be particularly important since eating preferences and behaviors are established during this period.<sup>43</sup> Using a nationally representative sample of foods commonly consumed by children in the U.S., this study empirically demonstrates the effect of processing classification system on conclusions regarding the relationship between processing and nutrient concentration, highlighting common and discordant aspects of these systems as well nutritional components that best align with processing level.

To our knowledge, no study has investigated the specificity of commonly used food processing classification systems using an objective outcome measure. The complexity of industrially produced foods in the U.S. is such that without precise category definitions and mutually exclusive categories, the potential for misclassification is high. The Nova system, as well as conclusions stemming from use of this system, have prompted extensive criticism from the scientific community.<sup>30,35,44,45</sup> In particular, critics have cited lack of rigorous definitions for processing categories,<sup>44</sup> undefined cutoff values for food additives and nutrients (despite reference to “high” amounts in ultra-processed foods<sup>46</sup>),<sup>44</sup> and coding methodologies that change over time.<sup>35</sup> Authors of the IFIC system have indirectly challenged conclusions based on use of the Nova system, stating that health professionals and the media mischaracterize processed food as “unnatural, unsafe and/or nutritionally inappropriate.”<sup>45</sup> Although based off the Nova system, the UNC system was developed specifically to categorize foods available in U.S. supermarkets.<sup>13</sup> The supplemental table provided by the authors categorizes all bar-coded foods by food groups, eliminating subjectivity.<sup>13</sup> We saw the highest inter-rater reliability between coders classifying foods with the UNC system, suggesting that a comprehensive framework for classifying foods is necessary to avoid misclassification.

As expected, the UNC and Nova systems had the highest level of agreement, but there was considerable discordance between all systems for moderately processed (level II) foods (Appendix 1). In particular, flavored milks were designated as moderately processed by the IFIC and UNC systems, and highly processed by Nova; most condiments and sauces were designated as moderately processed by the IFIC system, and highly processed by the Nova and UNC systems. The Nova system classified the most foods as highly processed (70%) while the IFIC system classified only 53% into the highest processing category, suggesting that the IFIC system underestimates the contributions of highly processed foods compared to Nova and UNC. Key differences in processing level assignment elucidate our results regarding the relationship between classification and nutrient concentration. As demonstrated in figure 2, plot C, there is greater spread and separation between processing level for the first and second linear discriminants compared to plots A and B. This indicates that processing classification is more predictive of nutrient concentration for the UNC system compared to Nova and

IFIC. For all systems, moderately processed foods are not well distinguished from minimally and highly processed foods by nutrient concentration, demonstrated by considerable overlap between observations classified as moderately processed and other processing categories. Results of the multinomial logistic regression analyses support the observation that all systems performed best when classifying highly processed foods; in other words, processing classification was most successful in distinguishing highly processed from minimally or moderately processed foods by nutrient profile. Higher added sugar and sodium levels were significant predictors of highly processed compared to minimally processed foods across all systems, suggesting that over-consumed nutrients may be better aligned with processing classification than under-consumed nutrients.

From the top 100 foods used in the present analysis, it is possible to look at specific foods that are predictive of nutrient concentration by processing level, and ones that are not. Foods such as nonfat milk and fresh fruits and vegetables are high in under-consumed nutrients, and low in over-consumed nutrients. Granulated sugar is also a less or “basic” processed food, however its nutrient profile is better aligned with those of highly processed foods. Similarly, plain peanut-butter and commercially-prepared salsa, classified as highly-processed by two of three systems, are each high in several under-consumed nutrients. Research considering only the effects of processing level, without examining the specific nutrient concentrations of foods commonly consumed by children, may misclassify the healthfulness of certain foods.

There is a limited research examining the relationship between processed food consumption and dietary quality in children. A 2005 study empirically investigated whether the increased prevalence of childhood obesity was associated with increased processed food consumption, finding that dietary energy density and food additives from the most processed foods may be a contributing factor.<sup>36</sup> This analysis defined processing by examining energy-dense foods and food residuals (non-nutritive food additives), preventing direct comparison with the present study. Our analysis did find that moderately processed foods are significantly more energy dense than minimally processed foods using the UNC system. Although we did not find significant effects for highly processed compared to less processed foods, there is a parallel increase in energy density with processing level for all systems, supporting the assumption that energy

density increases with processing level. Using reported foods from dietary records and 24 hour recalls, an analysis of ultra-processed food consumption and dietary quality in children from Colombia (using the Nova system) found that highly-processed foods had greater concentrations of sugar, sodium and trans-fatty acids, as well as lower levels of polyunsaturated fatty acids, vitamins A, B12, C and E, calcium and zinc.<sup>47</sup> The authors also found high levels of folate and iron in highly processed foods due to fortification.

Although these results cannot be directly translated to the U.S. food system, our findings support the conclusion that processing systems are better aligned with over-consumed nutrients, and highlights potential effects of food fortification on the alignment of processing level and dietary quality. Through extensive food fortification, highly processed foods may appear more similar to minimally and moderately processed foods with respect to under-consumed nutrients. In contrast, a study using the IFIC system examined children participating in NHANES 2003-2008 concluded that food from all processing levels contributed both under- and over-consumed nutrients as defined by the DGA.<sup>16</sup> Results do demonstrate that less processed foods contributed proportionally lower amounts of added sugars, sodium and energy, and higher amounts of several under-consumed nutrients. The authors point out that less processed foods are also higher in cholesterol; however, cholesterol is no longer considered a nutrient of concern according to the DGA.

This study has several notable strengths and limitations. As the first study to compare processing coding of foods commonly consumed by children between classification systems, we chose to limit our investigation to the top 100 most commonly consumed foods by children. These foods do not represent a comprehensive view of total diet. However, we used NHANES 2013-2014, a large, well-designed national survey that is representative of children in the U.S., which also utilizes the gold standard approach for dietary data collection.<sup>48</sup> In examining the relationship between processing classification and nutrient concentration, we examined standard portions of all foods as determined by the USDA; this standard amount is not necessarily reflective of what children actually eat, and may underestimate the role of processing level in determining nutrient concentrations in overall diets for foods eaten in large quantities (such as beverages), or overestimate the role for foods eaten in smaller quantities (such as

condiments). However, the top 100 most foods were chosen based on reported consumption of standard servings, suggesting that the foods are reflective of consumption in the general child population. By collapsing processing levels into three categories, we may miss pertinent differences between minimally and basic processed foods. However, very small samples of moderately processed (level two) foods prevented independent analysis, suggesting that future work may benefit from closer examination of the role of these foods in children's diets. The use of linear discriminant analysis in addition to multinomial logistic regression in the present study highlights key differences between systems, while highlighting potential strengths of processing classification with respect to dietary quality assessment; this methodology could be applied to larger food samples and populations to explore similar research questions.

## **CONCLUSIONS**

The impact of processing classification systems on conclusions regarding the relationship between processing level and nutrient density is significant. Without universally accepted definitions of processing levels and a rigorous framework to guide food coding, misclassifications will persist. Current processing systems may be better aligned with over-consumed dietary components, including added sugars and sodium, with our results highlighting the lack of ability of three processing systems to distinguish moderately processed foods from minimally or highly processed ones by nutrient concentration. In considering recommendations for children's diets, establishment of a nationally recognized system for the U.S. food system should consider the utility of processing classification to predict dietary quality, and may function best when interpreted as one aspect of diet within the context of traditional food and nutrient classifications.

## REFERENCES

1. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2010;51.
2. Singh GK, Siahpush M, Kogan MD. Rising social inequalities in US childhood obesity, 2003-2007. *Ann Epidemiol*. 2010;20(1):40-52.
3. Frederick CB, Snellman K, Putnam RD. Increasing socioeconomic disparities in adolescent obesity. *Proc Natl Acad Sci U S A*. 2014;111(4):1338-1342.
4. Hales C, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2017;288.
5. Nielsen S, Popkin B. Changes in beverage intake between 1977 and 2001. *Am J Prev Med*. 2004;27:205–210.
6. Nielsen S, Siega-Riz A, Popkin B. Trends in food locations and sources among adolescents and young adults. *Prev Med*. 2002;35:107–113.
7. Dunford EK, Popkin BM. 37 year snacking trends for US children 1977-2014. *Pediatr Obes*. 2018;13(4):247-255.
8. Popkin B. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr*. 2006;84:289-298.
9. Wrangham R. *Catching fire: how cooking made us human*. New York;2009.
10. Welch R, Mitchell P. Food processing: a century of change. *British Medical Bulletin*. 2000;56(1):1-17.
11. Carmody R, Wrangham R. Cooking and the human commitment to a high-quality diet. *Cold Spring Harbor Symposia on Quantitative Biology*. 2009;74.
12. Chapter 9—Federal Food, Drug, and Cosmetic Act. In. *Title 21—Food and Drugs*. Vol 21: US Food and Drug Administration, Department of Health and Human Services; 2016.
13. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.
14. Monteiro C, Levy R, Claro R, Ribeiro de Castro I, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11).
15. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003-2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S-2072S.
16. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients*. 2015;7(12):10076-10088.

17. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2016;6(3):e009892.
18. Fardet A, Rock E, Bassama J, et al. Current food classifications in epidemiological studies do not enable solid nutritional recommendations for preventing diet-related chronic diseases: the impact of food processing. *Adv Nutr*. 2015;6(6):629-638.
19. Mozaffarian D, Ludwig, D. Dietary Guidelines in the 21st Century— a Time for Food. *JAMA*. 2010;304(6):681-682.
20. Costa CS, Del-Ponte B, Assuncao MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr*. 2017;1-12.
21. Martin MA, Van Hook JL, Quiros S. Is socioeconomic incorporation associated with a healthier diet? Dietary patterns among Mexican-origin children in the United States. *Soc Sci Med*. 2015;147:20-29.
22. Peat J, Mellis C, Williams K, Xuan W. *Health science research: A handbook of quantitative methods*. Sydney, Australia: Allen & Unwin; 2002.
23. National Health and Nutrition Examination Survey Phone Follow-Up Dietary Interviewer Procedure Manual. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention.  
[http://www.cdc.gov/nchs/data/nhanes/nhanes\\_13\\_14/Phone\\_Follow-up\\_Dietary\\_Interviewers\\_manual.pdf](http://www.cdc.gov/nchs/data/nhanes/nhanes_13_14/Phone_Follow-up_Dietary_Interviewers_manual.pdf) Published 2014. Accessed.
24. U.S. Department of Agriculture, Agricultural Research Service. 2018. USDA Food and Nutrient Database for Dietary Studies 2013-2014. Accessed.
25. USDA National Nutrient Database for Standard Reference, Release 28. /nea/bhnrc/ndl. Updated Revised May 2016. Accessed December, 2017.
26. 2015–2020 Dietary Guidelines for Americans. 8th Edition. Available at <http://health.gov/dietaryguidelines/2015/guidelines/>. U.S. Department of Health and Human Services and U.S. Department of Agriculture;December 2015.
27. Moubarac JC, Parra DC, Cannon G, Monteiro CA. Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. *Curr Obes Rep*. 2014;3(2):256-272.
28. Monteiro C, Levy RB, Claro RM, Ribeiro de Castro IR, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11):2039-2049.
29. *Understanding our food communications tool kit*. Washington, DC: International Food Information Council;2010.
30. Dwyer JT, Fulgoni VL, 3rd, Clemens RA, Schmidt DB, Freedman MR. Is "processed" a four-letter word? The role of processed foods in achieving dietary guidelines and nutrient recommendations. *Adv Nutr*. 2012;3(4):536-548.
31. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly Processed and Ready-to-Eat Packaged Food and Beverage Purchases Differ by Race/Ethnicity among US Households. *J Nutr*. 2016;146(9):1722-1730.

32. O'Halloran SA, Lacy KE, Grimes CA, Woods J, Campbell KJ, Nowson CA. A novel processed food classification system applied to Australian food composition databases. *J Hum Nutr Diet*. 2017.
33. Landis J, Koch G. The Measurement of Observer Agreement for Categorical Data. *Biometrics*. 1977;33(1).
34. Andrade GC, da Costa Louzada ML, Azeredo CM, Ricardo CZ, Martins APB, Levy RB. Out-of-Home Food Consumers in Brazil: What do They Eat? *Nutrients*. 2018;10(2).
35. Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? *Curr Obes Rep*. 2017;6(4):420-431.
36. MacInnis B, Rausser, G. Does processing contribute to child obesity disparities? *Amer J Agr Econ*. 2005;87(5):1154-1158.
37. Hall K, Ayuketah A, Bernstein S, et al. Ultra-processed diets cause excess calorie intake and weight gain: A one-month inpatient randomized controlled trial of ad libitum food intake. *Under Review*. 2019.
38. Canella DS, Levy RB, Martins AP, et al. Ultra-processed food products and obesity in Brazilian households (2008-2009). *PloS one*. 2014;9(3):e92752.
39. Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *Int J Behav Nutr Phys Act*. 2015;12:160.
40. Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. *Nutr Metab Cardiovasc Dis*. 2015;25(1):116-122.
41. Tavares LF, Fonseca SC, Garcia Rosa ML, Yokoo EM. Relationship between ultra-processed foods and metabolic syndrome in adolescents from a Brazilian Family Doctor Program. *Public Health Nutr*. 2012;15(1):82-87.
42. Fiolet T, Srour B, Sellem L, et al. Consumption of ultra-processed foods and cancer risk: results from NutriNet-Santé prospective cohort. *BMJ*. 2018;360.
43. Birch L, Savage S, Ventura A. Influences on the Development of Children's Eating Behaviours: From Infancy to Adolescence. *Can J Diet Prac Res*. 2007;68(1).
44. Gibney MJ, Forde CG, Mullally D, Gibney ER. Ultra-processed foods in human health: a critical appraisal. *Am J Clin Nutr*. 2017;106:717-724.
45. Dwyer JT. Trailblazer Lecture: Why Are Processed Foods So Controversial? *J Acad Nutr Diet*. 2015;115(11):1871-1876.
46. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada ML, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2017:1-13.
47. Cornwell B, Villamor E, Mora-Plazas M, Marin C, Monteiro CA, Baylin A. Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. *Public Health Nutr*. 2017:1-6.
48. National Health and Nutrition Examination Survey. <https://www.cdc.gov/nchs/nhanes/index.htm>. Accessed November, 2017.

**TABLE 1:** Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing according to the IFIC<sup>a,15</sup>, Nova<sup>21</sup> and UNC<sup>b,13</sup> systems.

|      | Level I                                                                                                                                                                                                                 | Level II                                                                                                                                                                                     | Level III                                                                                                                                                                                                         | Level IV                                                                                                                                                                                                                         | Level V                                                                                                                | Level VI                                                                                                                                                                                   | Level VII                                                                                                                                                                                  |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IFIC | <b>Minimally processed:</b> Foods that require little processing or production, which retain most of their inherent properties.                                                                                         | <b>Foods processed for preservation:</b> Foods processed to help preserve and enhance nutrients and freshness of foods at their peak.                                                        | <b>Mixtures of combined ingredients;</b> Foods containing sweeteners, spices, oils, colors, flavors, and preservatives used for promotion of safety, taste, visual appeal.                                        | <b>Ready-to-eat processed:</b> Foods needing minimal or no preparation. Group subdivided into 'packaged ready-to-eat foods' and 'mixtures possibly store prepared.'                                                              | <b>Prepared foods/meals:</b> Foods packaged for freshness and ease of preparation.                                     | NA                                                                                                                                                                                         | NA                                                                                                                                                                                         |
|      | <b>Examples:</b> Milk, coffee, fruit, vegetables, meat and eggs.                                                                                                                                                        | Fruit juices; cooked, canned, or frozen vegetables and fruits.                                                                                                                               | Breads or rolls; sugars and sweeteners, cheeses, various condiments, and tacos or tortillas.                                                                                                                      | Soft drinks, sweets, salty snacks, cereal, lunchmeats, and alcoholic beverages.                                                                                                                                                  | Pizza, prepared meat dishes, pasta and prepared meals.                                                                 | NA                                                                                                                                                                                         | NA                                                                                                                                                                                         |
| Nova | <b>Unprocessed &amp; minimally processed:</b> Foods of plant origin or animal origin, shortly after harvesting, gathering, slaughter or husbanding; foods altered in ways that do not add or introduce any substance    | <b>Processed culinary ingredients:</b> Food products extracted and purified by industry from constituents of foods, or else obtained from nature, such as salt.                              | <b>Processed foods:</b> Manufactured by adding substances like oil, sugar or salt to whole foods, to make them durable and more palatable and attractive.                                                         | <b>Ultra-processed foods:</b> Formulated mostly or entirely from substances derived from foods. Processes include hydrogenation, hydrolysis; extruding, molding, reshaping; pre-processing by frying, baking.                    | NA                                                                                                                     | NA                                                                                                                                                                                         | NA                                                                                                                                                                                         |
|      | <b>Examples:</b> Fresh or frozen vegetables and fruits; grains including all types of rice; freshly prepared or pasteurized non-reconstituted fruit juices; fresh, dried, frozen meats; dried, fresh, pasteurized milk. | Plant oils; animal fats; sugars and syrups; starches and flours, uncooked 'raw' pastas made from flour and water, salt.                                                                      | Canned or bottled vegetables in brine; fruits preserved in syrup; tinned whole or pieces of fish preserved in oil; salted nuts; un-reconstituted processed meat and fish such as ham, bacon, smoked fish; cheese. | Confectionery; burgers and hot dogs; breaded meats; breads, buns, cookies (biscuits); breakfast cereals; 'energy' bars; sauces; cola, 'energy' drinks; sweetened yoghurts; fruit and fruit 'nectar' drinks; pre-prepared dishes. | NA                                                                                                                     | NA                                                                                                                                                                                         | NA                                                                                                                                                                                         |
| UNC  | <b>Unprocessed &amp; minimally processed:</b> Single-ingredient foods with no or very slight modifications that do not change inherent properties of the food as found in its natural form.                             | <b>Processed basic ingredients:</b> single isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food. | <b>Processed for basic preservation or precooking:</b> single minimally processed foods modified by physical or chemical processes for the purpose of preservation or precooking but remaining as single foods.   | <b>Moderately processed for flavor:</b> single minimally or moderately processed foods with addition of flavor additives for the purpose of enhancing flavor                                                                     | <b>Moderately processed grain products:</b> grain products made from whole-grain flour with water, salt, and/or yeast. | <b>Highly processed ingredients:</b> multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source. | <b>Highly processed stand-alone:</b> multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source. |
|      | <b>Examples:</b> Plain milk; fresh, frozen or dried plain fruit or vegetables; eggs, unseasoned meat; whole grain flour and pasta; brown rice; honey, herbs and spices.                                                 | Unsweetened fruit juice not from concentrate; whole grain pasta; oil, unsalted butter, sugar, salt.                                                                                          | Unsweetened fruit juice from concentrate; unsweetened/unflavored canned fruit, vegetables, legumes; plain peanut butter, refined grain pasta, white rice; plain yogurt.                                           | Sweetened fruit juice, flavored milk; frozen french fries; salted peanut butter; smoked or cure meats; cheese, flavored yogurt, salted butter.                                                                                   | Whole grain breads, tortillas or crackers with no added sugar or fat.                                                  | Tomato sauce, salsa, mayonnaise, salad dressing, ketchup.                                                                                                                                  | Soda, fruit drinks; formed lunchmeats; breads made with refined flours; pastries; ice-cream, processed cheese; candy.                                                                      |

<sup>a</sup>International Food Information Council<sup>b</sup>University of North Carolina at Chapel Hill

**Table 2.** Mean nutrient concentration per standard portion of the top 100 foods consumed by children 6-12 years old by processing level for the IFIC<sup>a,15</sup>, Nova<sup>21</sup> and UNC<sup>b,13</sup> systems, NHANES<sup>c</sup> 2013-2014.

| IFIC                              |              |         |              |         |              | Nova    |              |         |             |        |              | UNC     |              |         |              |         |              |         |
|-----------------------------------|--------------|---------|--------------|---------|--------------|---------|--------------|---------|-------------|--------|--------------|---------|--------------|---------|--------------|---------|--------------|---------|
| Processing level (n) <sup>d</sup> |              |         |              |         |              |         |              |         |             |        |              |         |              |         |              |         |              |         |
| Nutrient, mean (sd)               | Level 1 (18) |         | Level 2 (29) |         | Level 3 (52) |         | Level 1 (21) |         | Level 2 (9) |        | Level 3 (70) |         | Level 1 (24) |         | Level 2 (14) |         | Level 3 (62) |         |
| Energy (kcal)                     | 91.2         | (44.8)  | 107.2        | (85.7)  | 151.8        | (88.6)  | 98.6         | (55.3)  | 74.1        | (27.9) | 143.7        | (92.2)  | 103.0        | (54.2)  | 93.0         | (59.1)  | 145.5        | (95.0)  |
| Added sugars (g)                  | 1.7          | (6.3)   | 3.2          | (5.6)   | 9.8          | (10.9)  | 1.8          | (5.6)   | 2.5         | (7.0)  | 8.4          | (10.2)  | 2.2          | (6.8)   | 5.6          | (7.9)   | 8.3          | (10.3)  |
| Sat fat (g)                       | 0.8          | (1.5)   | 1.6          | (2.1)   | 1.7          | (2.1)   | 1.1          | (2.0)   | 1.9         | (1.1)  | 1.6          | (2.1)   | 0.9          | (1.4)   | 2.0          | (2.1)   | 1.7          | (2.2)   |
| Sodium (mg)                       | 46.1         | (69.8)  | 167.4        | (108.2) | 223.3        | (229.5) | 64.2         | (98.7)  | 160.2       | (80.0) | 210.4        | (207.8) | 88.2         | (120.5) | 119.5        | (72.6)  | 221.4        | (214.8) |
| Fiber (g)                         | 1.2          | (1.5)   | 0.5          | (0.7)   | 0.9          | (1.1)   | 1.0          | (1.4)   | 0.0         | (0.0)  | 0.9          | (1.0)   | 1.0          | (1.3)   | 0.5          | (0.8)   | 0.9          | (1.1)   |
| Potassium (mg)                    | 253.8        | (132.4) | 80.2         | (120.7) | 110.3        | (131.0) | 218.7        | (150.7) | 46.6        | (40.5) | 110.4        | (134.3) | 205.3        | (143.4) | 151.2        | (171.0) | 91.9         | (120.2) |
| Choline (mg)                      | 16.6         | (16.7)  | 17.6         | (32.4)  | 10.8         | (13.8)  | 14.5         | (16.3)  | 32.2        | (52.8) | 11.3         | (14.2)  | 23.5         | (34.6)  | 14.7         | (16.4)  | 9.9          | (13.2)  |
| Magnesium (mg)                    | 16.3         | (9.5)   | 10.1         | (11.0)  | 13.8         | (11.6)  | 14.9         | (10.1)  | 4.5         | (2.0)  | 13.8         | (11.8)  | 15.7         | (9.4)   | 13.7         | (12.6)  | 12.2         | (11.5)  |
| Calcium (mg)                      | 79.9         | (117.9) | 66.6         | (87.5)  | 52.0         | (87.2)  | 69.1         | (112.0) | 48.2        | (52.5) | 60.6         | (91.8)  | 65.0         | (104.9) | 113.7        | (121.4) | 48.0         | (77.1)  |
| Iron (mg)                         | 0.3          | (0.4)   | 0.6          | (0.6)   | 1.7          | (2.6)   | 0.4          | (0.5)   | 0.3         | (0.4)  | 1.5          | (2.3)   | 0.5          | (0.6)   | 0.3          | (0.3)   | 1.6          | (2.4)   |
| Vit A (mcg RAE)                   | 94.1         | (249.5) | 35.0         | (50.3)  | 47.7         | (89.0)  | 85.3         | (231.7) | 34.8        | (34.2) | 44.7         | (82.5)  | 77.5         | (217.4) | 44.7         | (51.7)  | 44.3         | (85.0)  |
| Vit D (mcg)                       | 0.7          | (1.3)   | 0.5          | (0.9)   | 0.3          | (0.6)   | 0.6          | (1.2)   | 0.4         | (0.5)  | 0.4          | (0.8)   | 0.6          | (1.1)   | 0.9          | (1.3)   | 0.2          | (0.5)   |
| Vit E (mg)                        | 0.2          | (0.2)   | 0.3          | (0.4)   | 0.6          | (0.7)   | 0.2          | (0.2)   | 0.3         | (0.4)  | 0.5          | (0.7)   | 0.3          | (0.4)   | 0.1          | (0.1)   | 0.5          | (0.7)   |
| Vit C (mg)                        | 21.0         | (31.6)  | 0.2          | (0.5)   | 3.0          | (5.5)   | 18.0         | (30.1)  | 0.0         | (0.0)  | 2.3          | (4.9)   | 15.7         | (28.7)  | 0.5          | (1.0)   | 2.5          | (5.1)   |

<sup>a</sup>International Food Information Council

<sup>b</sup>University of North Carolina at Chapel Hill

<sup>c</sup>National Health and Nutrition Examination Survey

<sup>d</sup>Processing classifications collapsed to three levels for analysis: for IFIC, levels four (ready-to-eat processed) and five (prepared foods/meals) were combined into level four. For UNC, levels two (basic – preservation) and three (basic – ingredient) were combined into level two; levels four (moderately – grain product) and five (moderately – flavor) were combined into level three, and levels six (highly – ingredient) and seven (highly) were combined into level four. Due to insufficient numbers of level two foods, levels one and two were combined for all systems.

**Table 3.** Multinomial logistic regression results for the association between classification level as determined by the IFIC<sup>a,15</sup>, Nova<sup>21</sup> and UNC<sup>b,13</sup> processing classification systems and nutrients of concern among 6-12 year olds in the U.S. population, NHANES<sup>c</sup> 2013-2014.

| Nutrient, mean (sd)                                | IFIC |               |             | Nova  |                  |             | UNC  |              |             |
|----------------------------------------------------|------|---------------|-------------|-------|------------------|-------------|------|--------------|-------------|
|                                                    | RRR  | 95% CI        | <i>p</i>    | RRR   | 95% CI           | <i>p</i>    | RRR  | 95% CI       | <i>p</i>    |
| <b>Level 1 (base outcome, minimally processed)</b> |      |               |             |       |                  |             |      |              |             |
| <b>Level 2 (moderately processed)</b>              |      |               |             |       |                  |             |      |              |             |
| Energy (kcal)                                      | 1.01 | (0.98, 1.05)  | 0.44        | 0.98  | (0.93, 1.04)     | 0.58        | 0.96 | (0.93, 1.00) | <b>0.03</b> |
| Added sugars (g)                                   | 1.05 | (0.87, 1.28)  | 0.58        | 1.19  | (0.89, 1.58)     | 0.24        | 1.25 | (1.05, 1.49) | <b>0.01</b> |
| Sodium (mg)                                        | 1.03 | (1.00, 1.07)  | <b>0.03</b> | 1.04  | (1.01, 1.08)     | <b>0.02</b> | 1.01 | (1.00, 1.02) | <b>0.10</b> |
| Saturated fat (g)                                  | 0.65 | (0.28, 1.53)  | 0.32        | 1.09  | (0.41, 2.93)     | 0.86        | 3.33 | (1.21, 9.16) | 0.02        |
| Fiber (g)                                          | 3.10 | (0.81, 11.83) | 0.10        | 0.00  | - , -            | 0.99        | 1.69 | (0.44, 6.48) | 0.45        |
| Potassium (mg)                                     | 0.97 | (0.94, 0.99)  | <b>0.01</b> | 0.95  | (0.89, 1.01)     | 0.08        | 1.00 | (0.99, 1.01) | 0.87        |
| Calcium (mg)                                       | 1.02 | (0.98, 1.06)  | 0.40        | 1.01  | (0.98, 1.04)     | 0.63        | 1.02 | (0.99, 1.05) | 0.12        |
| Iron (mg)                                          | 0.32 | (0.08, 1.35)  | 0.12        | 24.18 | (0.03, 20875.62) | 0.36        | 0.89 | (0.20, 4.03) | 0.88        |
| Vit D (mcg)                                        | 2.00 | (0.05, 88.05) | 0.72        | 0.54  | (0.00, 66.41)    | 0.80        | 0.18 | (0.01, 2.93) | 0.23        |
| <b>Level 3 (highly processed)</b>                  |      |               |             |       |                  |             |      |              |             |
| Energy (kcal)                                      | 1.00 | (0.97, 1.04)  | 0.86        | 0.99  | (0.97, 1.01)     | 0.54        | 0.99 | (0.97, 1.01) | 0.16        |
| Added sugars (g)                                   | 1.25 | (1.03, 1.51)  | <b>0.02</b> | 1.21  | (1.05, 1.39)     | <b>0.01</b> | 1.23 | (1.07, 1.40) | <b>0.00</b> |
| Sodium (mg)                                        | 1.04 | (1.01, 1.07)  | <b>0.02</b> | 1.02  | (1.00, 1.03)     | <b>0.01</b> | 1.01 | (1.00, 1.02) | <b>0.02</b> |
| Fiber (g)                                          | 1.98 | (0.56, 6.98)  | 0.29        | 1.51  | (0.66, 3.44)     | 0.32        | 1.43 | (0.58, 3.54) | 0.44        |
| Saturated fat (g)                                  | 1.01 | (0.44, 2.31)  | 0.98        | 0.98  | (0.57, 1.71)     | 0.96        | 2.18 | (0.85, 5.55) | 0.10        |
| Potassium (mg)                                     | 0.99 | (0.97, 1.00)  | 0.11        | 0.99  | (0.99, 1.00)     | 0.22        | 1.00 | (0.99, 1.00) | 0.42        |
| Calcium (mg)                                       | 1.01 | (0.97, 1.06)  | 0.57        | 1.01  | (0.98, 1.03)     | 0.52        | 1.01 | (0.99, 1.04) | 0.22        |
| Iron (mg)                                          | 1.04 | (0.38, 2.83)  | 0.94        | 1.11  | (0.54, 2.27)     | 0.78        | 1.57 | (0.81, 3.07) | 0.19        |
| Vit D (mcg)                                        | 0.16 | (0.00, 6.82)  | 0.34        | 0.46  | (0.04, 5.18)     | 0.53        | 0.06 | (0.00, 0.83) | <b>0.04</b> |

<sup>a</sup>International Food Information Council

<sup>b</sup>University of North Carolina at Chapel Hill

<sup>c</sup>National Health and Nutrition Examination Survey

<sup>d</sup>Processing classifications collapsed to three levels for analysis: for IFIC, levels four (ready-to-eat processed) and five (prepared foods/meals) were combined into level four. For UNC, levels two (basic – preservation) and three (basic – ingredient) were combined into level two; levels four (moderately – grain product) and five (moderately – flavor) were combined into level three, and levels six (highly – ingredient) and seven (highly) were combined into level four. Due to insufficient numbers of level two foods, levels one and two were combined for all systems.

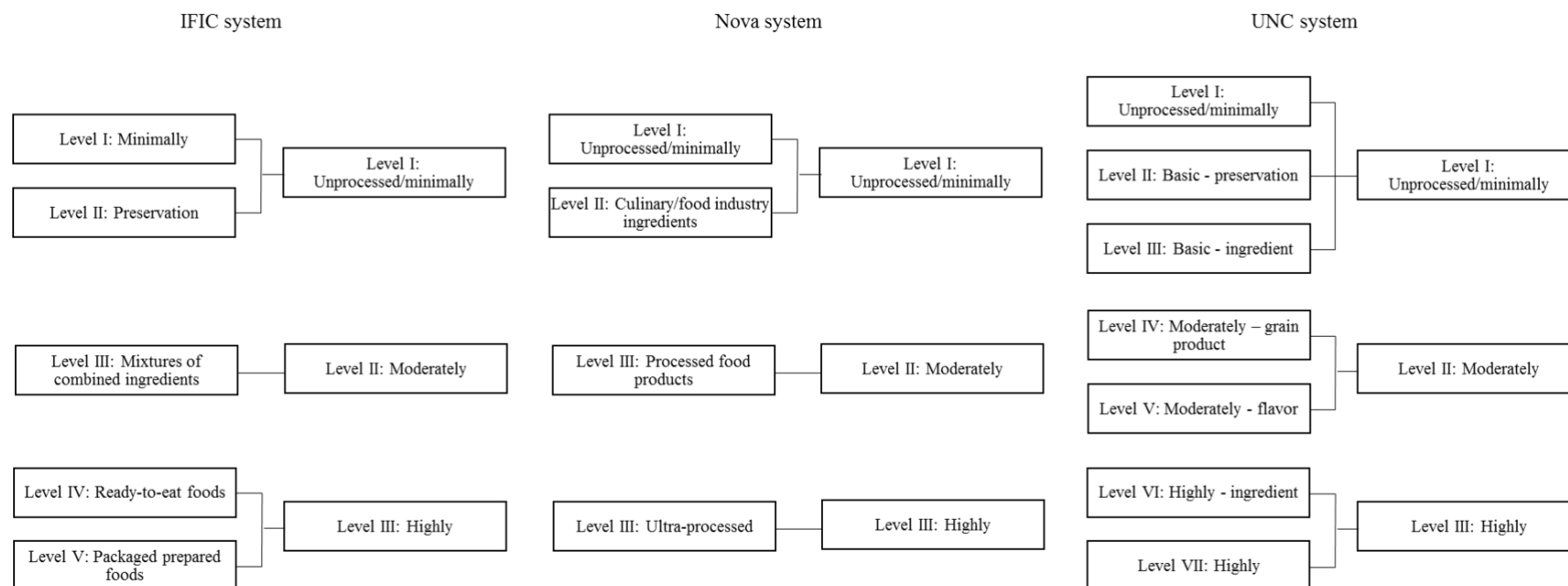
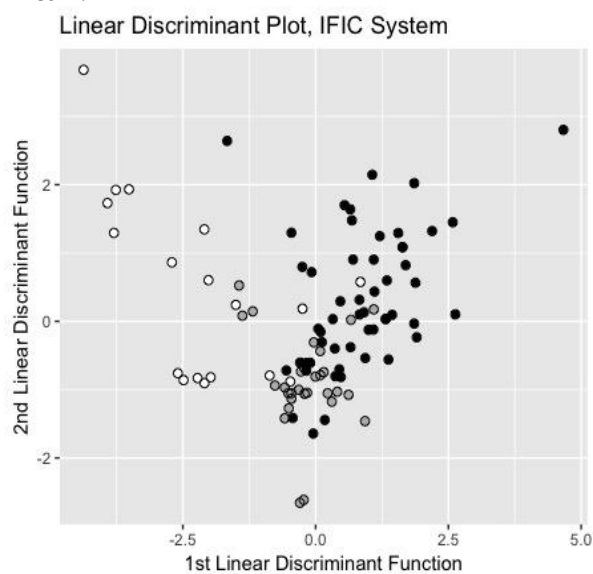
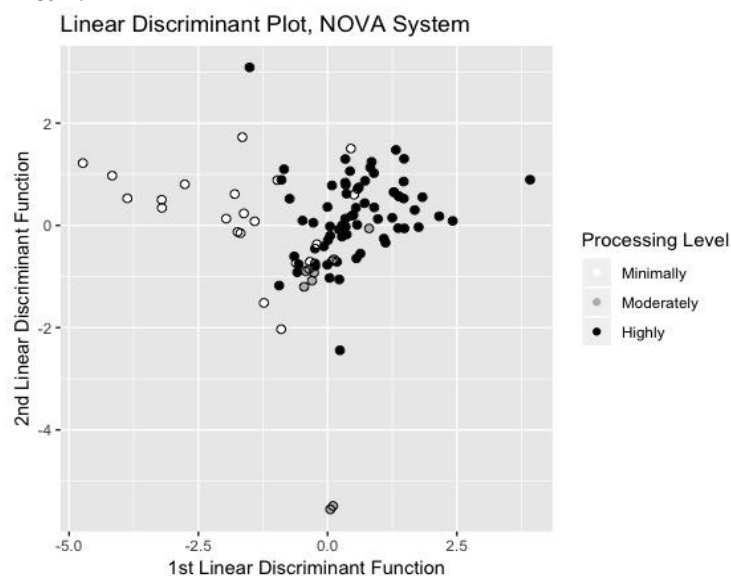


**Figure 1.** Original and final category assignment for foods as classified by the International Food Information Council (IFIC), Nova and University of North Carolina at Chapel Hill (UNC) systems

Plot A.



Plot B.



Plot C.

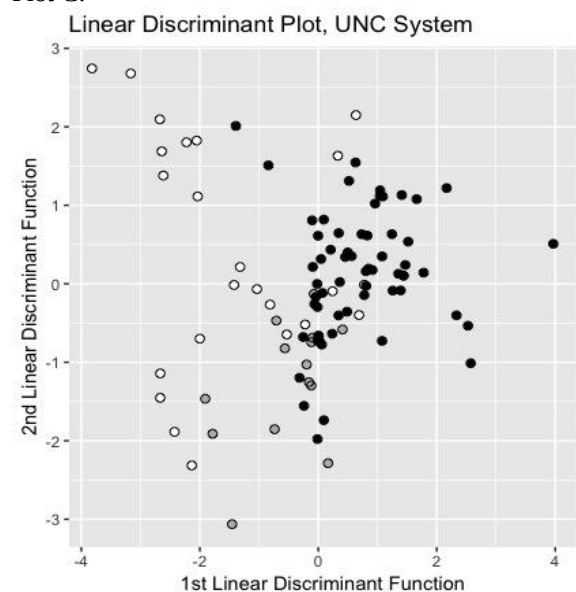


**Figure 2.** The top 100 foods consumed by children 6–12 years old (NHANES 2013-2014) by processing level, plotted within the first two linear discriminants for the International Food Information Council (IFIC), Nova and University of North Carolina at Chapel Hill (UNC) systems according to predicted classification level.

## **CHAPTER IV: Chemicals, cans and factories: how grade school children think about processed foods**

### **Authors**

Rachel Bleiweiss-Sande, MS<sup>1</sup>; Jeanne Goldberg, PhD, RD<sup>1</sup>; Erin Whitney Evans, PhD, RD<sup>2</sup>; Kenneth Chui, PhD, MPH<sup>1</sup>; Caitlin Bailey, MS<sup>1</sup> and Jennifer Sacheck, PhD<sup>3</sup>

<sup>1</sup>Friedman School of Nutrition Science and Policy, Tufts University

<sup>2</sup>Warren Alpert Medical School, Brown University

<sup>3</sup>Milken Institute School of Public Health, The George Washington University

### **ABSTRACT**

*Background:* Recent evidence suggests that high rates of processed food consumption may contribute to current levels of overweight and obesity among children in the United States, yet little is known about their understanding of processed foods. This study sought to determine how children interpret terms related to food processing; whether their classification of foods according to processing level is consistent with those used in research, and whether they associate the degree of processing with healthfulness.

*Methods:* Ten focus groups with children in the 4<sup>th</sup>-6<sup>th</sup> grade (n = 53) were conducted at four elementary and after-school programs serving predominantly low-income, racial/ethnic minority students. Children were asked about the meaning of phrases related to food processing, how they would classify a variety of foods according to their processing level, and the healthfulness of the foods using interactive activities. Focus groups were audio-recorded, transcribed verbatim and analyzed for key themes using NVivo 12 (QSR International).

*Results:* Participants had a largely accurate understanding of phrases commonly used to describe processing level. As expected, comprehension increased with age. Children's understanding of unprocessed foods was well-aligned with research classifications, while concordance of highly processed foods with research classifications varied. Five primary themes regarding the way children classified foods according to their processing level emerged: type and amount of added ingredients; preparation method; packaging and storage; change in physical state or appearance, and growing method. Most children associated processing level with healthfulness, describing unprocessed foods as healthier. The most common reasons provided for the unhealthfulness of processed foods were added ingredients, including 'chemicals' and 'sugar.'

*Conclusions:* This study demonstrates that children have a working knowledge of processed foods, but their understanding is not always consistent with classification systems used in research. Children's strong associations between degree of processing and healthfulness suggest that this topic may offer a novel approach for nutrition education.

## BACKGROUND

Poor dietary habits, obesity and related metabolic diseases among children continue to be a major public health concern in the United States (US).<sup>1,2</sup> Experts argue that a focus on nutrients has led to the proliferation of highly processed food products that meet major nutrient targets, but are detrimental to overall dietary quality and health.<sup>3</sup> In response, researchers have called for a shift from nutrient-based dietary recommendations to food-based guidance.<sup>3-5</sup> There is also a need for simple, effective communication strategies to convey nutrition information to consumers, particularly children from racial/ethnic minority and low-income backgrounds who are at a greater risk for obesity.<sup>1,6-10</sup>

As interest in the effects of food processing on human health has gained traction among researchers, several classification systems, which distinguish between the processing level of foods, have been used to conduct research in the US.<sup>11-15</sup> The NOVA system, developed in Brazil, classifies foods into four categories based on the nature, extent and purpose of industrial food processing; it is the most widely used food processing classification system in nutrition research.<sup>16,17</sup> Researchers at the University of North Carolina at Chapel Hill have adapted the NOVA system to the US food supply, developing a classification scheme that categorizes foods available in supermarkets by degree of processing.<sup>11</sup> The International Food Information Council devised a system that categorizes foods based on the complexity of processing and resulting changes to the food.<sup>15</sup> These three systems are often simplified to a three-tiered model, categorizing foods as minimally, moderately or highly processed.<sup>18</sup>

Studies stemming from these classification systems have reached various conclusions regarding the relationship between processing, obesity and health in children. While processed food is widely perceived to be a major contributor to childhood obesity and related health problems globally,<sup>13,19-21</sup> alternate studies conducted in the US have underlined the positive effects of processing on food safety and affordability, and the wide variability in nutrient content across processed products.<sup>15,18,22,23</sup> Despite this contradiction, what we do know is that foods categorized as highly-processed, containing high amounts of sugar, saturated fat, and sodium, are detrimental to health.<sup>2,24,25</sup> Evidence

suggests that children with overweight and obesity consume diets with an overabundance of highly-processed foods.<sup>20,26-29</sup>

As evidenced by the multiple classification systems currently used in research, the term “processed food” lacks a clear, concise definition that can be communicated to a range of audiences, and there is no universally accepted definition of highly or ultra-processed food.<sup>18</sup> While understanding the contribution of highly processed foods to health is important, of immediate urgency is the need to reduce the consumption of such foods,<sup>29</sup> especially among socioeconomically disadvantaged children who are at a greater risk of developing obesity and related co-morbidities.<sup>21,30</sup> Research is therefore needed to identify how children from low-income communities and/or racial and ethnic minority groups perceive processed foods, including their classification and healthfulness.

This study sought to determine how children interpret terms related to food processing; whether their classification of foods according to processing level is in line with research-based classification systems, and whether they associate the degree of processing with healthfulness. Investigating how children think and talk about different foods, as well as their understanding of processing classification, may offer important insight into policy and communication tactics to encourage healthier eating patterns.

## METHODS

Focus group research is designed to give the researcher insight into what people think and why, in a congenial and non-threatening environment.<sup>31</sup> For exploratory research on the topic of processed foods, focus groups provide an ideal research method to investigate children’s perspectives.<sup>31,32</sup> The focus group format overcomes some of the drawbacks of individual interviews, such as the desire to please the researcher, since the discussion frames the participant as the expert, and shyer individuals may feel more comfortable in a small group environment.<sup>31</sup>

*Recruitment and sample.* During Spring 2017, a pilot focus group was held with 3<sup>rd</sup> – 6<sup>th</sup> graders to determine if the questions and activities were age-appropriate. Based on these results, 3<sup>rd</sup> graders, who demonstrated limited understanding of processing language, were dropped from the sample. Children in the 4<sup>th</sup>-6<sup>th</sup> grade were recruited from four urban schools or afterschool programs in the Greater Boston area. Sites were

selected to provide representation from a range of sociodemographic backgrounds, including a high percentage of students from racial/ethnic minority groups and low-income families. Five principals or program directors were contacted and four agreed to allow us to recruit students from their schools or programs. At each site, students were recruited through short, in-class presentations and given an information packet to take home. The packets included parent consent and child assent forms, a demographic survey, and details about the study. To participate, children had to be enrolled in the 4<sup>th</sup>-6<sup>th</sup> grade, speak English, have a parent willing to allow their child to participate in the focus group, and return their completed consent packet within one week of recruitment.

Recruitment took place from Fall 2017 to Spring 2018. After each session, researchers reviewed transcripts to identify new concepts; focus groups were held until no new themes emerged.<sup>33</sup> Fifty-seven students participated in the study: sixty-one students returned completed consent packets, and of these eight were unable to participate due to scheduling conflicts. Ten focus groups were conducted by the research team with five to seven children in each group.

All study procedures were approved by the Tufts University Institutional Review Board, and by individual school district research boards as necessary. In addition to written assent, verbal assent was obtained from all participants at the start of each focus group.

*Instrument development.* A semi-structured moderator's guide was developed to investigate children's thoughts and perceptions on the topic of processed food. The first set of questions asked children how they would interpret words and phrases related to processing. The questions were drawn from a nutrition education curriculum targeting nutrition and eco-friendly packaging.<sup>34</sup> Three "kid-friendly" terms to describe unprocessed and processed foods (*fresh*, *man-made* and *machine-made food*) were chosen for discussion based on this curriculum. Children were then asked about the meaning of unprocessed and processed foods. These questions aimed to determine children's familiarity with words related to processing and to establish a lexicon for the children to discuss processing during the next activity. To explore the topic of classification, children were shown pictures of nine food products printed on large cards, asked to talk about how they would arrange these foods from least to most processed.

Cards were presented in random order, one by one, to the group and placed in a line on the table. According to processing classification systems used in research, three of the foods were unprocessed (an apple, a tomato and plain milk), three were moderately processed (applesauce, tomato sauce in a can, and chocolate milk), and three were highly processed (flavored apple juice drink, ketchup and a milkshake).<sup>11,17</sup> All children were asked their opinion about how to classify the food cards and to explain their reasoning during the session. Finally, children were asked to discuss how they would rank the same foods according to healthfulness and to explain why. Based on pilot focus group results, the number of food cards was reduced from nine to six to limit the length of the focus group, eliminating the milk, chocolate milk and milkshake.

*Data collection procedures.* Focus groups were held at each site during a day and time deemed convenient by school staff, separated by grade level (4<sup>th</sup>, 5<sup>th</sup> or 6<sup>th</sup>). A focus group moderator and note-taker from the research team, and at least one school staff representative, were present during each session. Focus groups lasted between 30 and 40 minutes and were audio-recorded. Children received a \$5 gift card to thank them for their participation.

*Analytical methods.* The analysis team included two research assistants and one researcher (author 1). The research assistants transcribed all audio recordings verbatim along with field notes from the focus groups. Content analysis using an inductive approach was used to code transcripts. An inductive approach relies on the data to drive theme identification, allowing children's perspectives on the unexplored topic of food processing to be revealed and compared for thematic consistency or divergence. Members of the analysis team independently identified codes from each transcript, then discussed results to develop a list of categories and sub-categories. A codebook was developed based on the initial list. Using an iterative approach, the codebook was further refined and expanded into themes and sub-themes based on patterns that emerged from the data. Once a final codebook was established, inter-rater reliability was tested among the analysis team using two randomly chosen transcripts. After ensuring 80% agreement between coders, transcripts were coded by one analyst. NVivo12 (QSR International, Doncaster, VIC, Australia) was used to facilitate analyses.

## RESULTS

Children from four school districts participated in the study, with the majority coming from district 3 (**Table 4**). There was a greater percentage of female (58.5%) versus male participants, with a roughly even split between grade level. Almost three-quarters (73.6%) of the sample was from a racial/ethnic minority group and 56.6% were eligible for free- or reduced-price lunch, characteristics that are reflective of the districts overall. Students actively participated in focus group discussions and expressed excitement about the topic of food and its classification.

### Meaning of words related to processing

With respect to words and phrases related to processing level, children had an inconsistent understanding of meanings in the context of food processing. Understanding increased with age. **Table 5** provides example questions and representative quotes from this section of the focus group as well as researcher definitions of terms.

*Fresh food.* Most children related the term to recently harvested foods, and considered fruits and vegetables to be the best examples of fresh foods. Several children in 5<sup>th</sup> and 6<sup>th</sup> grade (from different focus groups) mentioned organic foods as fresh, referring specifically to vegetables. Two 6<sup>th</sup> grade students made explicit references to processing: “It’s food that hasn’t been processed, or it may have been packaged but in an open package, like at a farmer’s market.” Food with expiration dates, such as milk, came up in multiple groups. Several 4<sup>th</sup> grade students had an alternate interpretation, describing “hot foods” that were just cooked.

*Man-made food.* Fifth and 6<sup>th</sup> grade children brought up various junk foods, foods with multiple ingredients, and baked goods to describe man-made. Fourth grade children across multiple focus groups had a more literal interpretation of man-made as “made by people using their hands,” or “when your mommy or daddy makes something for you.” One boy observed that the term could be interpreted as processed foods (“the people process it”) or homemade foods (“I’m thinking it’s something people make at home”), summarizing the two main interpretations that emerged from focus groups. Although no other student explicitly referenced processing, most described man-made food with terms related to processing, such as packaging and added ingredients.

*Machine-made food.* Across all focus groups, factory imagery came up most often, along with references to specific machines (coffee machines, vending machines, ice-cream dispensers), and factories themselves. While candy was often mentioned as an example, including candy canes, jelly bellies and “the Hershey factory,” others referred to machine-made as ‘greasy foods’ from fast-food restaurants.

*Unprocessed foods.* Approximately one-third of 4<sup>th</sup> graders reported being unfamiliar with the term ‘unprocessed.’ Several younger participants summed up the term as “just fruits and vegetables,” while others interpreted the term to mean “not ready to eat” or an “indigestible” food such as gum. It is worth noting that children from two 4<sup>th</sup> grade focus groups switched the definitions of ‘unprocessed’ and ‘processed’ due to confusion with the prefix ‘un-.’ This trend began after one child in the group had trouble distinguishing between the two words, and others followed suit. Fifth and 6<sup>th</sup> grade students mentioned foods from farmer’s markets, such as eggs, bread, and produce, which “don’t have the chemicals added.” Two participants from different groups described an experience of picking food (corn and apples) as associated with unprocessed. Finally, students from three separate groups cited a lack of machines or factories as indicators of unprocessed foods.

*Processed foods.* As expected, children offered opposite definitions for processed foods relative to their definition of unprocessed. In the case of focus groups employing ‘flipped’ definitions, children mentioned vegetables, fruits, and “healthy foods” as processed. In two groups, several children described processed food as prepared food that is ready to eat. Several offered junk foods and “fatty stuff” as examples from separate groups. Participants from the 6<sup>th</sup> grade referenced machines, including factory machines and smaller, restaurant appliances such as coffee machines, foods with “chemicals,” and canned foods. Children from several groups brought up YouTube videos that explained the process of making hot dogs and chicken nuggets, which they described as processed foods. As the 4<sup>th</sup> grader explained, “it showed me hot dogs are processed and machine-made and made me not want to eat ‘em anymore.” Children from 6<sup>th</sup> grade had a similarly negative reaction to a video of chicken nugget production.

### Classification of foods by processing level

Despite some lack of clarity in defining processing level, children revealed a surprising degree of confidence in discussing how they would classify foods. As described above, six cards with photographs of foods were presented to the focus group, displaying an apple, tomato, applesauce, tomato sauce, flavored apple juice, and ketchup. Most children categorized the apple (74%) and tomato (68%) as the least processed items; the applesauce (68%) and juice (53%) as moderately processed, and the tomato sauce (57%) and ketchup (79%) as the most processed. Children referenced the type and amount of added ingredients; preparation method; packaging and storage; change in physical state or appearance, and the perceived growing method of foods to support their classification decisions. **Table 6** provides relevant quotations from children that are representative of each theme discussed.

*Added ingredients.* Children across all grades referenced the amount and type of added ingredients (perceived or actual), to classify the six foods. The addition, or lack, of chemicals was singled out as the most common determinant of processing level for children. As one 5<sup>th</sup> grader explained, “I’ve seen the label on tomato sauce before, and there’s a lot of words I don’t know ... a lot of stuff like chemicals, which means it’s probably more processed.” The opposite was true for children’s explanations of less-processed foods (generally the tomato and apple): “The apple is a fresh food, nothing changed, no chemicals added, nothing” (6<sup>th</sup> grade). Artificial colors and flavors were referenced as well, but less frequently than ‘chemicals.’ Sugar and salt, often mentioned in the same sentence, were repeatedly used to support categorizations of more processed foods. Children believed, in varying degrees, that the applesauce, tomato sauce, juice and ketchup had added sugar and salt. Several 6<sup>th</sup> grade children pointed out that homemade food often has less added sugar and salt, and therefore might be less processed.

*Preparation method.* The use of machinery was often mentioned, along with creative imagery of metal parts and appliances, to support the classification of tomato sauce, applesauce, juice and ketchup as the most processed. Some children saw the tomato sauce and ketchup as requiring the most steps (making them more highly processed), while others reasoned that the juice or applesauce were the most preparation intensive. Just as several children differentiated between the ingredients added to homemade vs.

commercially-made foods, a few suggested that the act of making a food at home would render it less processed.

*Moderator:* So you think of the tomato sauce as more processed because of how it's made?

"Yeah, it's different than how I would make it cause at home I would just take some tomatoes, take that spoon right there, and make it fresh and honest." (Girl, 5<sup>th</sup> grade)

One 4<sup>th</sup> grade participant observed that the processing of store-bought applesauce may depend on the type purchased, "because some of them just mash the apple into bits until it's liquidy, but some they do more." Others brought up the time required to make a food as an indicator of processing, with items like ketchup requiring "a lot of tomatoes and that would take so much time."

*Packaging & storage.* The tomato sauce can, applesauce container, juice box and ketchup bottle came up as indicators of a higher processing level, while lack of a container signified less processing to children. When asked which foods were the least processed, one 4<sup>th</sup> grader pointed to the apple and tomato: "These two, because they are the only things not in a bottle or something like that." Packaging represented food going through a dramatic "change" or "process." Storage and expiration days were tightly linked to packing. While less processed food "doesn't last as long," packaged foods were described as likely to sit on store shelves for extended periods. Sixth grade participants in one group fixated on the potential for food contamination from the packaging itself, as further evidence that packaged products are highly processed.

*Change in physical state or sensory experience.* In discussing processing level, many students pointed to a change in color, texture, state (solid to liquid) or taste as rationale for processing level categorization. Several argued that the applesauce and juice were only slightly processed, since the final products were still recognizable as apples. Several students, upon considering the journey from tomato or apple to sauce or juice, seemed baffled by the presumed level of processing that took place: "The ketchup started out like that [pointing to tomato], whole, and now it's that [pointing to picture of ketchup], not whole, it's liquid! How can it go through all that and not be processed?" Others noted a change in color from bright red tomato to dark sauce or paste, as well as the "soured" taste of ketchup as evidence of greater processing.

*Growing method.* Most children agreed that the apple and tomato were the least processed foods, reasoning that they were “grown, and that’s a natural process,” as described by a 6<sup>th</sup> grade participant. Fourth grade children had a similar perception of the tomato and apple as “natural” products, and several specifically cited the lack of human or machine involvement as a mark of unprocessed foods. A 4<sup>th</sup> grade student explained, “Nobody makes [the apple], it’s not man-made, it just grows.” In two of the 6<sup>th</sup> grade focus groups, several students came up with a more complex processing classification scheme based on whether the fruits had been sprayed with preservatives, farmed with growth hormones, or were genetically modified.

*Moderator:* You’re saying the apple and tomato are unprocessed?

“Well yeah, but it kinda depends on how it was grown. If a seed was put in the ground and it grew without any growth hormones then that would be one thing...” (6<sup>th</sup> grade) Another student added that if the apple and tomato were organic, they would be less processed since “organic food tends to not have all the genetically modified things within it.” Of note, children who mentioned specific growing methods seemed to reference growth hormones, genetic modification and organic interchangeably.

### **Healthfulness of foods**

Children’s discussion of healthfulness of the six foods centered on the number and type of added ingredients, with several students noting that processing level was associated with healthfulness. Just as participants focused on the effects of added sugar and ‘chemicals’ on processing level, these ingredients were often referenced in the context of healthfulness. The sauces, ketchup and juice were all singled out as containing “sugars and chemicals,” making them “probably not healthy at all.” Several 4<sup>th</sup> grade students offered a quantitative measure of healthfulness based on the amount of apple or tomato they perceived to be in the product: “Apples are 100% healthy. I think the apple juice is half and half because it’s half apples and the other half is chemicals and stuff they use for flavor.” Across focus groups, four students who professed to dislike tomato sauce categorized it as the least healthy. While an explicit association between processing level and healthfulness was vocalized only twice, many students discussed themes from processing classification to determine healthfulness, including added ingredients, as well

as packaging, preparation, and the perceived growing method. Several students chose the tomato sauce as the least healthy “because it’s in a can.” One 4<sup>th</sup> grade student reasoned that applesauce made at home is healthier “since you can ask your mom not to put sugar in it.”

## DISCUSSION

In the U.S., no study has systematically examined children’s familiarity with processed food language. The present study addresses this gap by asking a diverse group of children how they interpret vocabulary associated with food processing, classify foods according to their processing level, and consider the healthfulness of foods from different processing categories. Our findings suggest that children are aware of the concept of food processing, but their perceptions of how foods are classified by processing level differ from criteria used in food processing classification systems.

Children’s interpretation of the terms *fresh*, *man-made* and *machine-made foods* in this study provide guidance on the types of phrases understood by children. Fresh food was most often associated with minimally processed foods – fruits and vegetables, eggs, milk and meats – but children also cited unexpired, packaged products. The term ‘nature-made,’ which is less likely to be associated with prepared foods, might align better with students’ understanding of unprocessed, but this term was not tested in focus groups. Man-made food, though described by some as junk food and packaged products, consistently elicited literal interpretations from younger children. Machine-made food was better aligned with highly processed foods, bringing up images of hot dogs, candy and chips. These “kid-friendly” terms require further testing to ensure that they are understood by broader youth samples. Future work could test terms used in processing classification systems (minimally, moderately and highly processed).

When presented with the task of discussing processed foods or classifying foods by processing level, children employed certain visual “clues.” Added ingredients came up as the most salient theme for children to categorize foods by processing level, a criterion that aligns well with the Nova classification system. In this system, unprocessed foods are defined, in part, by the fact that they are single ingredients, and highly processed as multi-ingredient mixtures. Although the health outcomes linked to excess sugar and salt

are not understood by children (one 6<sup>th</sup> grade boy described salt as bad for health because it “turns to sugar in the blood”), they expressed a desire to limit these ingredients. Furthermore, children demonstrated a nuanced understanding of home-cooked food as potentially healthier based on one’s control over ingredients. This presents an opportunity to draw associations between processing and healthfulness based on the number and type of added ingredients on food labels, and to encourage home-made meals. The addition of “chemicals” was brought up throughout the focus groups, but children were unable to articulate further on the nature of these added ingredients. While many packaged and processed products contain preservatives, flavorings and emulsifiers that may be described as “chemicals,” an over-emphasis on these ingredients may encourage distrust of processed foods. Linking processing to added ingredients like sugar and salt is a simpler and more actionable message, as fresh or “nature-made” foods do not have these added ingredients.

Packaging emerged as another central theme guiding children’s categorization. Containers, particularly cans, served as a clear indicator to children of high processing level. A similar line of reasoning was used by participants in a project investigating food literacy in disadvantaged, Canadian youth, who perceived eating too many “boxed” foods as unhealthy.<sup>35</sup> In the present study, children focused on the addition of “chemicals” necessary to make packaged products last longer. This focus seems to be linked to children’s perception of “added ingredients” in processed foods. A few children even ventured that canned, boxed and bottled products are less healthy due to the potential for contamination. As one 6<sup>th</sup> grade girl explained, “something in a can or a box can get chemicals or bacteria stuff in there.” The notion of “added chemicals” as indicative of processing is somewhat misguided. Ingredients such as ascorbic acid, which prevents oxidation, may be interpreted as unhealthy chemicals. Children’s purported concern for food safety is worrisome since it suggests a blanket mistrust of packaged products, and a black and white interpretation of the relationship between packaging and health. Teaching children to differentiate between ingredients for preservation (ascorbic acid) and flavoring (salt and sugar) may be a useful approach to introduce the topic of processing. Furthermore, a more nuanced view of packaging is important to encourage fruit and vegetable consumption from a variety of sources, and to discourage stigma

associated with packaged goods. Explaining the basics of food safety, including the principles behind food preservation, would allow children to view preserved vegetables as a good alternative to fresh.

The topic of healthfulness elicited strong opinions from children, but their logic was often flawed. Many children described the ketchup as unhealthy “because of how it’s made,” but were unable to describe the process. Similarly, the apple and tomato were almost universally described as healthy because they were “grown.” Several children insisted that they avoid unhealthy foods such as juices and other “sweetened” drinks, while others claimed that tomato sauce is unhealthy simply because they don’t like the way it tastes. Food preferences certainly may bias children’s opinions of healthfulness. On the other hand, added ingredients were the most cited contributor to unhealthy qualities of the foods, which further aligns with other indicators of processing level.

Experts have suggested that children’s nutrition education is an ideal starting point to positively influence eating patterns that persist into adulthood.<sup>6</sup> A 2018 review by Murimi et al.<sup>36</sup> of factors associated with successful nutrition education interventions in children identified parent engagement, identification of specific behavioral outcomes, teacher training, adequate duration (at least 6 months) and use of age-appropriate activities as key components of interventions targeting elementary school children. Recent research has focused on dietary patterns, rather than single foods or nutrients, as a superior determinant of obesity risk; this approach, however, represents a less-defined and wider focus for consumer-targeted education and messaging efforts. In the context of food-based dietary recommendations, food processing may offer a novel strategy to encourage healthier eating among youth that is well-aligned with dietary recommendations.

While this study sheds light on the unexplored topic of children’s conceptualization of food processing, there are several limitations. Lessons gleaned from a population of low-income, ethnically diverse children from an urban setting may not be generalizable to children in other settings. Second, voluntary participation may have been a source of selection bias, favoring children who were more knowledgeable about food and nutrition or who had a greater interest in the subject. Lastly, we were unable to segregate groups by gender, English-language learner status or socio-economic status.

Studying how these factors influence perceptions and knowledge of processing would be useful in developing tailored curricula.

## **CONCLUSION**

The topic of food processing has gained traction among science and research communities, but understanding child perceptions of processing is necessary to translate findings into actionable messages for at-risk populations. Low-income and minority youth, who are at a high risk of obesity and associated chronic diseases, may benefit from targeted nutrition education efforts on the topic of food processing and its relationship to health. This study demonstrates that children have a working knowledge of processing that could be leveraged to encourage healthier eating patterns; however, their understanding is not always consistent with the classification systems used in research. The vocabulary used by researchers and consumers to talk about processing must be reconciled to translate findings into actionable messages. More research is needed to develop a common language that is accepted by the research and food manufacturing communities and is comprehensible to consumers. In addition, more research is needed to develop educational approaches to teach the concept of processing to children. Parents, who are generally responsible for food purchasing and preparation, are an important target for future research on the topic of food processing perceptions, as are school teachers and administrators.

## REFERENCES

1. Hales C, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2017;288.
2. Banfield EC, Liu Y, Davis JS, Chang S, Frazier-Wood AC. Poor Adherence to US Dietary Guidelines for Children and Adolescents in the National Health and Nutrition Examination Survey Population. *J Acad Nutr Diet*. 2016;116(1):21-27.
3. Mozaffarian D, Ludwig, D. Dietary Guidelines in the 21st Century— a Time for Food. *JAMA*. 2010;304(6):681-682.
4. Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutr*. 2009;12(5):729-731.
5. Fardet A, Rock E, Bassama J, et al. Current food classifications in epidemiological studies do not enable solid nutritional recommendations for preventing diet-related chronic diseases: the impact of food processing. *Adv Nutr*. 2015;6(6):629-638.
6. Rowe S, Alexander N, Almeida N, et al. Food science challenge: translating the dietary guidelines for Americans to bring about real behavior change. *J Food Sci*. 2011;76(1):R29-37.
7. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2010;51.
8. Fahlman MM, McCaughtry N, Martin J, Shen B. Racial and socioeconomic disparities in nutrition behaviors: targeted interventions needed. *J Nutr Educ Behav*. 2010;42(1):10-16.
9. Frederick CB, Snellman K, Putnam RD. Increasing socioeconomic disparities in adolescent obesity. *Proc Natl Acad Sci U S A*. 2014;111(4):1338-1342.
10. Wang Y, Beydoun MA. The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev*. 2007;29:6-28.
11. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.
12. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly Processed and Ready-to-Eat Packaged Food and Beverage Purchases Differ by Race/Ethnicity among US Households. *J Nutr*. 2016;146(9):1722-1730.
13. Martinez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. *Popul Health Metr*. 2017;15(1):6.
14. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2016;6(3):e009892.

15. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003-2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr.* 2012;142(11):2065S-2072S.
16. Monteiro C, Levy R, Claro R, Ribeiro de Castro I, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública.* 2010;26(11).
17. Moubarac JC, Parra DC, Cannon G, Monteiro CA. Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. *Curr Obes Rep.* 2014;3(2):256-272.
18. Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? *Curr Obes Rep.* 2017;6(4):420-431.
19. Moodie R, Stuckler D, Monteiro C, et al. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet.* 2013;381:670-679.
20. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? *Am J Clin Nutr.* 2014;99(1):162-171.
21. MacInnis B, Rausser, G. Does processing contribute to child obesity disparities? *Amer J Agr Econ.* 2005;87(5):1154-1158.
22. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients.* 2015;7(12):10076-10088.
23. Dwyer JT, Fulgoni VL, 3rd, Clemens RA, Schmidt DB, Freedman MR. Is "processed" a four-letter word? The role of processed foods in achieving dietary guidelines and nutrient recommendations. *Adv Nutr.* 2012;3(4):536-548.
24. Malik VS, Popkin BM, Bray GA, Despres JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care.* 2010;33(11):2477-2483.
25. Reedy J, Krebs-Smith SM. Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. *J Am Diet Assoc.* 2010;110(10):1477-1484.
26. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *The American Journal of Clinical Nutrition.* 2013;98(4):1084-1102.
27. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA. Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Pediatrics.* 2013;131(1):14-21.
28. Zanovec M, O'Neil CE, Cho SS, Kleinman RE, Nicklas TA. Relationship between whole grain and fiber consumption and body weight measures among 6- to 18-year-olds. *J Pediatr.* 2010;157(4):578-583.
29. Ambrosini GL. Childhood dietary patterns and later obesity: a review of the evidence. *Proc Nutr Soc.* 2014;73(1):137-146.

30. Slining MM, Mathias KC, Popkin BM. Trends in food and beverage sources among US children and adolescents: 1989-2010. *J Acad Nutr Diet*. 2013;113(12):1683-1694.
31. Heary C, Hennessy E. The use of focus group interviews in pediatric health care research. *J Pediatr Psych*. 2002;27(1):47-57.
32. Morgan M, Gibbs S, Maxwell K, Britten N. Hearing children's voices: methodological issues in conducting focus groups with children aged 7–11 years. *Qualitative Research* 2002;2(1):5-20.
33. Patton M. *Qualitative evaluation and research methods*. Newbury Park (CA): Sage Publications Inc; 1990.
34. Hubbard KL, Must A, Eliasziw M, Folta SC, Goldberg J. What's in children's backpacks: foods brought from home. *J Acad Nutr Diet*. 2014;114(9):1424-1431.
35. Desjardins E. *"Making something out of nothing": Food literacy among youth, young pregnant women and young parents who are at risk for poor health*. Ontario, Canada: Public Health Ontario;2013.
36. Murimi MW, Moyeda-Carabaza AF, Nguyen B, Saha S, Amin R, Njike V. Factors that contribute to effective nutrition education interventions in children: a systematic review. *Nutr Rev*. 2018;76(8):553-580.

**Table 4.** Sociodemographic characteristics of child focus group participants (N = 53)

|                                                    |       |       |
|----------------------------------------------------|-------|-------|
| <b>Sex, n (%)</b>                                  |       |       |
| Male                                               | 21    | (40)  |
| Female                                             | 31    | (59)  |
| Transgender                                        | 1     | (1)   |
| <b>Age (years), mean (sd)</b>                      | 10.41 | (1.1) |
| <b>Grade, n (%)</b>                                |       |       |
| 4th grade                                          | 19    | (36)  |
| 5th grade                                          | 16    | (30)  |
| 6th grade                                          | 18    | (34)  |
| <b>Race/ethnicity, n (%)</b>                       |       |       |
| Non-Hispanic white                                 | 14    | (26)  |
| Non-Hispanic black                                 | 12    | (23)  |
| Hispanic                                           | 25    | (47)  |
| Multiracial/Asian/other                            | 2     | (4)   |
| <b>Free/reduced price lunch eligibility, n (%)</b> |       |       |
| Yes                                                | 30    | (57)  |
| No                                                 | 23    | (43)  |

**Table 5.** Sample quotes and example foods to support children's descriptions of terms related to processing

| Common/researcher definition                                                                                                                                                               | Representative quote                                                                                                                                                                                                                                                                                                                      | Common example foods given                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Fresh food</b>                                                                                                                                                                          | <b><i>What does 'fresh food' mean?</i></b>                                                                                                                                                                                                                                                                                                |                                                                       |
| Generally used to describe food that has not been preserved; may also be used to describe unexpired foods, or just-cooked/prepared foods.                                                  | "Cold food. Food that stays in the refrigerator." (B, 4th)<br>"... food that you just now got, like for example, 'I just now plucked strawberries.'" (G, 5th)<br>"... foods that were not individually wrapped and can't stay for too long. Like milk could be... fresh because it expires in 7 days. So that's pretty fresh." (B, 6th)   | Fruits, vegetables, meats, milk, "organic foods"                      |
| <b>Man-made food</b>                                                                                                                                                                       | <b><i>What does 'man-made food' mean?</i></b>                                                                                                                                                                                                                                                                                             |                                                                       |
| Man-made food often refers to packaged or fast foods, as an antonym to 'nature-made.'                                                                                                      | "... when a man or a boy does everything. They would have to do a lot of work to make the food." (B, 4th)<br>"Makes me think of, Doritos, Sour Patch, and stuff that's not good for you." (G, 5th)<br>"I think of processed food, like packaged and made in factories." (G, 6th)                                                          | Hamburgers, hot dogs, chips, pizza                                    |
| <b>Machine-made food</b>                                                                                                                                                                   | <b><i>What does 'machine-made food' mean?</i></b>                                                                                                                                                                                                                                                                                         |                                                                       |
| Similar to man-made, machine-made is used to describe mass-produced, packaged foods.                                                                                                       | "It's when someone puts something in a machine and the machine just gives you the food already done for you to eat." (G, 4th)<br>"... food that's made in a factory like candy." (G, 5th)<br>"Those are like processed foods. Like foods that go through a specific process in machines and get ... treated in a different way." (B, 6th) | Candy, hot dogs, French-fries                                         |
| <b>Unprocessed food</b>                                                                                                                                                                    | <b><i>What does 'unprocessed food' mean?</i></b>                                                                                                                                                                                                                                                                                          |                                                                       |
| Single-ingredient foods with no or slight modifications that do not change inherent properties of the food as found in its natural form.                                                   | "... food that didn't get put in the store." (B, 4th)<br>"I think it's a food that you eat whole instead of cutting it up." (G, 5th)<br>"... unmodified, or unchanged ... something like a strawberry. Nothing would be different, just a natural food." (G, 6th)                                                                         | Fruits, vegetables, breads, milk, eggs, "junk food"                   |
| <b>Processed food</b>                                                                                                                                                                      | <b><i>What does 'processed food' mean?</i></b>                                                                                                                                                                                                                                                                                            |                                                                       |
| Highly-processed foods are multi-ingredient industrially formulated mixtures or dishes processed to the extent that they are no longer recognizable as their original plant/animal source. | "Maybe food that's cooked and ready for you." (G, 4th)<br>"... foods that have gone through factories and have more chemicals." (B, 5th)<br>"Canned food, because they have to change all the stuff that goes into a can - it has to go through an elaborate process in a factory." (B, 6th)                                              | Empanandas, fast foods, canned foods, hot dogs, fruits and vegetables |

**Table 6.** Quotations to support themes related to how children classify foods by processing level

| <b>Theme</b>                                                 | <b>Moderator: How would you put these foods into categories from least to most processed? Why?</b>                                                                                                                            |
|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Added ingredients</i></b>                              | "The tomato sauce isn't that processed because not really anything is added to it." (G, 4th)                                                                                                                                  |
| Chemicals                                                    | "The ketchup has the chemicals in it to make it taste more interesting." (G, 4th)                                                                                                                                             |
| Sugar and salt                                               | "The apple juice - they had to do a lot to it to get the juices out of the apple and add the sugar in." (B, 4th)                                                                                                              |
|                                                              | "The stuff that has more sugar in it... and you think it tastes better, is the one that has been processed more, because it has more chemicals and sugar or salt put in it." (G, 5th)                                         |
| Colors and flavors                                           | "With juices they come in different flavors, so they put different...maybe, different artificial flavors in it that makes it more processed." (B, 6th)                                                                        |
| Number of ingredients                                        | "Ketchup is the most highly processed. 'Cause out of all these, ketchup has the most ingredients, and sugar." (B, 6th)                                                                                                        |
| <b><i>Preparation method</i></b>                             | "To make applesauce ... maybe they have some kind of formula and machines ... and the containers go in the pulleys and then they squirt apple sauce out of it and it goes right into the cup ... So it's a process." (B, 5th) |
|                                                              | "[Processing] depends on the number of steps. So foods that have steps...like meat. The first step would be hunting it and then adding flavor and then cooking it, and then maybe selling it?" (G, 6th)                       |
| <b><i>Packaging &amp; Storage</i></b>                        | "Well, this is a dead giveaway that [the applesauce] is very processed: It's in a container. That means something happened to it." (B, 6th)                                                                                   |
|                                                              | "... most canned stuff doesn't expire until a year. So that's really processed 'cause they must have put some serious chemicals in, just for it to preserve for a year." (B, 6th)                                             |
| <b><i>Change in physical state or sensory experience</i></b> | "I think the juice and the applesauce are a little processed. Because it's only grinded and smashed." (G, 5th)                                                                                                                |
|                                                              | "Ketchup is so modified. See the picture of that bright red tomato? And then look at the dark red paste. They change it so much that I don't think it's a tomato anymore." (G, 6th)                                           |
| <b><i>Growing method</i></b>                                 | "I think the apple is not processed? Yeah because nobody makes it, it's not man-made. It grows on trees." (G, 4th)                                                                                                            |
|                                                              | "I'm saying the apple and the tomato are a little processed because we don't know if it was really fresh ... if the farmer put like some type of coating so that the bugs won't eat it." (B, 6th)                             |

## **CHAPTER V: Perceptions of processed foods among low-income and immigrant parents**

### **Authors**

Rachel Bleiweiss-Sande, MS<sup>1</sup>; Jeanne Goldberg, PhD, RD<sup>1</sup>; Erin Whitney Evans, PhD, RD<sup>2</sup>; Kenneth Chui, PhD, MPH<sup>1</sup>; Jennifer Sacheck, PhD<sup>3</sup>

<sup>1</sup>Friedman School of Nutrition Science and Policy, Tufts University

<sup>2</sup>Warren Alpert Medical School, Brown University

<sup>3</sup>Milken Institute School of Public Health, The George Washington University

### **ABSTRACT**

*Background:* Parent-aimed guidance on the topic of processed foods may help to limit highly-processed foods in children's diets, but little is known about parent understanding and perceptions of these products.

*Aims:* To determine how parent perceptions of processing align with processing classification systems used in research, and to identify opportunities for future research in communicating information about processed foods.

*Methods:* Six focus groups with lower-income, racial/ethnic minority and immigrant parents of 4<sup>th</sup>-6<sup>th</sup> graders (n = 37) were conducted. Parents were asked to discuss their views on terminology related to food processing, classification of foods according to their processing level, the healthfulness of select foods, and criteria for choosing snacks for their children. Focus groups were analyzed using content analysis and an inductive approach using NVivo 12 (QSR International).

*Results:* Thirty mothers and seven fathers participated. Two-thirds (62%) were foreign-born; most (38%) identified as Hispanic. The term "processing" lacked consistent meaning among parents, with variation by immigrant status. Participants associated highly processed foods with convenience, packaging, and added ingredients; "less-processed" versions of foods (e.g. fresh; homemade) were perceived as healthier. Children's preferences were the main criteria for choosing snacks. Foreign-born parents were more likely to associate processed foods with positive characteristics (e.g. properly cooked).

*Conclusions:* The concept of food processing is an area of misconception among parents, providing an opportunity for education that may be extended to larger audiences. A universally accepted definition of food classification by processing level is necessary to effectively communicate the link between processing and healthfulness.

## BACKGROUND

In the U.S., there is a growing consensus that the proliferation of energy-dense, convenient processed foods available to American children is an important factor in the current obesity epidemic.<sup>1,2</sup> Highly processed foods are often high in saturated fat, added sugar and salt.<sup>3</sup> A study of national dietary data showed that highly-processed foods made up 57.9% of daily energy intake,<sup>4</sup> while a study of children's foods brought from home to school found that 61% of energy in lunches was from highly-processed foods.<sup>5</sup> The percentage in snacks was even higher (78%)<sup>5</sup> suggesting that limiting the intake of these products may improve children's nutritional status.

In recent years, racial and ethnic inequalities in nutrition and obesity in children have increased, even as national rates have begun to plateau.<sup>6,7</sup> Non-Hispanic black and Hispanic children from lower socioeconomic status (SES) backgrounds demonstrate relatively lower intake of nutrients and recommended food groups,<sup>8</sup> and are at a higher risk of obesity.<sup>7</sup> While changes to school food nutrition policies and wellness legislation may have a significant impact on current and future generations, it is reasonable to assume that additional approaches to address the obesity problem are needed.<sup>9</sup>

Parents play a key role in determining child eating patterns as the principal household food purchasers and “gatekeepers,” and may impact eating behavior through role modelling and socio-cultural factors.<sup>10,11</sup> Research shows consistent associations between parent and child intake of fruits and vegetables,<sup>10</sup> and numerous studies have demonstrated the influence of parent intake on child sugar-sweetened beverage (SSB) consumption.<sup>12</sup> Reaching parents, particularly recent immigrants and those from low-SES households, presents a particular challenge due to time constraints and logistical problems,<sup>13</sup> language barriers,<sup>14</sup> and lack of cultural sensitivity.<sup>15</sup> The concept of food processing may provide a novel and straightforward focus for messages that encourage under-consumed food groups such as fruits, vegetables and dairy, and discourage consumption of energy-dense snacks and SSBs.<sup>16</sup>

Food processing classification systems, which categorize foods based on the extent and purpose of industrial processing, have recently been advanced as a way to quantify the relationship between processed food intake and health outcomes.<sup>17-19</sup> Several systems have been developed, each with unique criteria and language to classify

foods.<sup>3,20,21</sup> Researchers have used these processing classification systems to examine processed food purchases at the household level in the U.S.,<sup>21,22</sup> as well as contributions to dietary intake and quality, with varying conclusions regarding the link between processing, diet quality and health.<sup>4,18</sup>

Despite growing interest in food processing, diet and health outcomes in the scientific community, there has been minimal effort to translate these findings into processing-related recommendations for U.S. consumers. Parents from minority and low-SES households, whose children are at a higher risk of obesity and associated conditions, may benefit from an understanding of the effects of processing on the healthfulness of foods to make informed food choices for their children. An understanding of the perceptions of processed foods among parents is needed as a first step to effectively communicate details about processing classification systems.

This qualitative study investigated perceptions of food processing, including interpretations of related terms; food processing classification systems; associations between processing and healthfulness and impact on snack choice among parents from culturally diverse, urban school districts. This research sought to determine how consumer perceptions of processing align with processing classification systems used in research, and to identify opportunities for future research in communicating information about processed foods. Exploring parent understanding of this topic may help to inform interventions, communication strategies and tactics that target healthier eating patterns in vulnerable populations.

## METHODS

**Recruitment and sample.** Parents were recruited from schools and afterschool programs participating in a related child focus group study from three large, urban school districts.<sup>23</sup> Details of school site selection are described in detail elsewhere.<sup>23</sup> Briefly, sites were chosen to represent a range of sociodemographic characteristics, including a high percentage of low-income, immigrant and racial/ethnic minority families. All parents of 4<sup>th</sup>-6<sup>th</sup> graders were eligible to participate in focus groups, regardless of whether their child was participating in the ongoing child study. Parents were recruited through flyers distributed at parent-teacher conferences and school events. Eligibility

criteria included having a child in the 4<sup>th</sup>-6<sup>th</sup> grade, verbal English proficiency, and willingness to complete a demographic survey. Recruitment and focus groups took place during spring 2018. Thirty-seven parents volunteered to participate in the study. Although all participants reported English fluency, several schools provided translators onsite to assist with survey completion and comprehension of the study protocol. These translators were available during the focus group in case of comprehension issues. Since all groups were conducted in English, sessions were not stratified by immigration status. All study procedures were approved by the Tufts Institutional Review Board, and by individual school district research boards as required. Written and verbal consent was obtained from all participants at the start of each focus group.

**Instrument development.** A semi-structured moderator's guide was developed in conjunction with the child focus group study.<sup>23</sup> A pilot focus group was conducted with five parents from the target demographic to determine if the child questions translated well to parents. Pilot focus group participants reported that they appreciated phrasing and activities tailored to a low-literacy audience, since several spoke English as a second language. The focus group guide is described in detail elsewhere.<sup>23</sup> Briefly, parents were asked about the meaning of words related to processing, how they would classify a variety of foods according to processing level, and their thoughts on the healthfulness of these foods using interactive activities. An additional set of questions asked about the types of snacks parents usually buy or prepare for their children, and their criteria for choosing those snacks. In the first section, the group was shown cards with the phrases "fresh food," "man-made food," "machine-made food," "unprocessed food," and "processed food," and were asked to discuss how they interpret the terms as a group. Next, six cards with photographs of foods were shown to the group. Parents were asked how they would classify the foods according to their level of processing and to discuss their thoughts on the healthfulness of the foods. The cards had pictures of an apple, a tomato, an individual applesauce container, canned tomato sauce, apple juice drink in a box and a ketchup bottle. Finally, parents were asked about the types of snacks they buy for their children.

**Data collection procedures.** Focus groups were held on weekdays at school sites, following school drop-off hours or during afterschool periods depending on school staff

and parent availability. After each session, researchers reviewed transcripts to identify new concepts; focus groups were held until no new themes emerged.<sup>24</sup> A total of six focus groups were held, with five to eight parents per group. One member of the research team (author 1) moderated all focus groups with the help of a note-taker. All parents reported full comprehension of the forms and focus group procedures. Focus groups were audio-recorded and lasted between 30 and 40 minutes. Parents received a gift card to thank them for their participation.

**Analytical methods.** Two research assistants and one researcher (author 1) conducted all analyses. Audio recordings were transcribed verbatim, including pertinent field notes from the focus groups. Themes were identified using content analysis and an inductive approach to develop a codebook. Researchers worked independently to identify codes, then discussed results to establish discrete categories and sub-categories. These categories formed a provisional codebook that was further refined and expanded based on patterns that emerged from the transcripts. An iterative approach was used to resolve focus group themes and establish a final codebook. Inter-rater reliability among the research team members was assessed using two randomly chosen transcripts. Satisfactory agreement was set a-priori at 80%. Once this level of agreement was reached, one analyst coded all transcripts using NVivo 12 (QSR International, Doncaster, VIC, Australia).

## RESULTS

Thirty-seven parents from three school districts participated in the study (**Table 7**). Most participants were female (81%), with a mean age of 40 (*sd* 5.9). The majority identified as Hispanic (38%), reported an education level of high school or less (41%), and had a child who was eligible for free- or reduced-price lunch (70%). Almost two-thirds (62%) were foreign-born.

### Meaning of words related to processing

Parents' interpretation of terms related to processing level varied by immigrant status, with several inconsistencies emerging within focus groups. Relevant quotes and definitions of common processing terms based on the Nova classification system<sup>20</sup> are presented in **Table 8**.

*Fresh-foods.* Parents commonly associated *fresh-foods* with fruits and vegetables, with some noting that organic produce is “especially fresh.” Several contrasted fresh foods with those that are frozen. Foreign-born parents in different focus group consistently described anything prepared at home as fresh.

*Man-made foods.* This phrase was described inconsistently across focus groups. Several women interpreted the phrase literally to mean “food made by men,” joking that this was a rarity in their household. Among U.S.-born participants, man-made was described as food that is manufactured, unhealthy, and convenient. Several foreign-born women said they were unfamiliar with the term, while others suggested that it meant home-cooked, and therefore healthy food.

*Machine-made foods.* Parents consistently interpreted machine-made as processed and packaged foods. Foreign-born participants frequently referenced frozen and canned foods, while U.S.-born participants referenced hot dogs and packaged snacks. There was a consensus across groups that machine-made foods are less healthy than “fresh” or home-made foods.

*Unprocessed foods.* Definitions of unprocessed food ranged from “foods without chemicals” to natural and organic foods. Most brought up fruits and vegetables, foods grown in a garden, and “fresh foods” as examples. Several parents reported hearing the word “processed” more than unprocessed. Foreign-born participants were more likely to report that they did not understand the term. In five out of six groups, at least one foreign-born participant interpreted the term to mean “foods that are not ready to eat,” or foods that are not yet cooked.

*Processed foods.* Most parents said they were familiar with the term “processed” and reported hearing it often. Multiple participants used packaging to define processed items. Several parents associated processing with convenience. Across several groups, foreign-born participants interpreted the term to mean cooked foods that are “ready to eat.”

### **Classification of foods by processing level.**

As described above, parents were shown six cards with food images (an apple, tomato, applesauce cup, canned tomato sauce, flavored apple juice box, ketchup bottle),

and were asked to classify the foods as unprocessed, moderately processed or highly processed. All parents classified the apple and tomato as unprocessed. Most considered the applesauce (91%) and tomato sauce (86%) moderately processed. Some parents (14%) also considered the apple drink to be moderately processed. Most agreed that the ketchup (95%) and apple drink (86%) were highly processed, while a smaller percentage argued that the tomato sauce (14%) and applesauce (9%) were highly processed as well. There were no major differences in food classification by immigration status. Parents based their classification decisions on three major themes: convenience/preparation, added ingredients, and packaging. Example quotations from each theme, including healthfulness, are presented in **Table 9**.

*Convenience/preparation.* The theme of convenience and ease of preparation came up frequently across focus groups. Processed foods were often described as “easy” products for families short on time, including canned foods and microwaveable meals. Mothers referenced the difference between highly processed and homemade in their classifications, explaining that homemade tomato sauce is time-consuming but less processed than their store-bought counterparts.

*Packaging.* Just as packaging was used to define processed food in the first section of the focus group, both U.S.- and foreign-born parents again brought up the presence/absence of containers as a way to classify foods. Parents associated cans, in particular, with highly processed foods. Packaging was also an indicator of shelf-life, and thus processing level, for parents.

*Added ingredients.* Parents referenced the addition of sugar, salt, chemicals and “unknown ingredients” to support their processing classifications. U.S.-born parents mentioned added sugar and salt more than foreign-born to explain processing level. The addition of chemicals was an important determinant of processing level among all parents. Several mentioned that “ingredients you can’t pronounce” was a good indicator of high processing.

*Healthfulness.* While discussing major themes to classify foods by processing level, parents frequently referenced the healthfulness of foods. There was agreement that foods in cans are more convenient, but less healthful. Across focus groups, several parents said processed foods tend to be higher in salt and sugar. One foreign-born father

said he stopped serving juice to his children, and now offers only water and whole milk, based on advice from the family doctor. U.S.-born mothers in other focus groups described a similar decision to stop buying juice for their children based on a doctor's advice regarding the sugar content of juice drinks. Several foreign-born fathers spoke about unprocessed foods as always being the most healthful.

### **Snack choices**

Health (70%) and children's food preferences (68%) were the top two criteria cited when asked about choosing and preparing snacks for their children. Other criteria included convenience (17%) and cost (14%). One foreign-born mother said she considers processing level and tries to buy unprocessed foods. A few mothers explained that their purchasing decisions were based on their own health concerns, such as losing weight or improving their overall diet. Fathers were more likely to report their children's preferences as the most important factor. One father explained "I try to get him used to other things, but he likes chips, so that's what I buy." Another father said he worries about food waste, so sticks with foods he trusts his children to eat.

Both U.S.-born and foreign-born parents expressed a sense of pride in serving healthful snacks. Others stressed that they buy treats, such as chips and candy, but in portion-controlled packages to prevent overeating. A few foreign-born mothers said they are dedicated to cooking everything from scratch, despite the time commitment, since they believe it is important to their children's health.

## **DISCUSSION**

This study clearly demonstrates that the term "processing" lacked consistent meaning among low-income U.S. and foreign-born parents. Individual understanding of the term may influence parents' choices of foods for their family. This finding is not surprising given the lack of a regulated definition of processing, in general, and of its sub-categories. Yet the majority of food purchases are considered highly processed,<sup>22</sup> and the word itself is commonly used to give food recommendations. It is also clear that the public associates certain values with processing.

As the burden of obesity increases globally, several countries have issued food regulations and policies concerning highly processed foods that can serve as models for

U.S. policy makers. For example, Mexico passed legislation to tax SSBs and the Pan-American Health Organization developed a nutrient profiling model to guide front of package labeling for highly processed products.<sup>25</sup> In 2014, Brazil became the first country to issue national recommendations specifically addressing processing level in their Dietary Guidelines for the Brazilian Population.<sup>26</sup> The guidelines offer advice to decrease consumption of ultra-processed foods and increase consumption of minimally-processed and traditional dishes, according to processing levels defined by the Nova system.<sup>27</sup>

Since there is no nationally accepted system for classifying foods according to processing level in the U.S., the potential for misclassification and inaccurate perceptions of processing are high as demonstrated by our results. Some parents in the present study saw minimally processed foods such as frozen fruits and vegetables as highly processed, due to misperceptions about the relationship between freezing and nutrient degradation. Tomato sauce and applesauce, which are moderately processed products,<sup>20</sup> were seen as highly processed by some parents due to “chemicals” and other additives. The misalignment between consumer perceptions of processing and researcher classifications undoubtedly influences how information about processed foods is communicated. While participants were familiar with processed food language (such as highly versus unprocessed foods), the findings indicate that they have not received formal guidance about the role of processed foods in healthy eating patterns. Without a commonly understood syntax to discuss processed foods, misperceptions will persist. Universally accepted definitions of processing, which do not yet exist among researchers, are critical to communicate accurate information about positive aspects of food processing to consumers.<sup>16</sup>

A key finding from this study was parents’ reported reliance on child preferences as their primary criteria for choosing snacks, despite a desire to limit unhealthful and highly processed foods in their children’s diets. As one mother put it, “When I give the cookies she asks for they are eaten, but usually the banana comes home.” Increased snacking has been investigated as a potential factor in the rise of child obesity. A recent study demonstrated a significant increase in per capita energy intake from snacks from 1977-2014 among children.<sup>28</sup> Notably, those from the lowest SES groups as well as ethnic minority children had the greatest increase in SSB, grain-based dessert, and salty

snack intake.<sup>28</sup> Other research has corroborated the finding that energy from children's snacks is largely derived from refined, processed food sources, suggesting that these convenient foods are an appropriate target to reduce highly processed foods in children's diets, particularly those from lower income and minority families.<sup>29</sup>

The topic of food processing presents several challenges for delivering health and nutrition messages, particularly for foreign-born families. Dietary acculturation is thought to be an important factor in current rates of obesity among second generation adolescents in the U.S.<sup>30-32</sup> For example, Latino children's requests for "Americanized" foods were identified as a major influence in family dietary patterns in a systematic review of the relationship between acculturation and diet.<sup>31</sup> Foreign-born parents also perceived fresh foods to be more readily available and better tasting in their home countries than in the U.S.<sup>31</sup> While the present study did not measure acculturation level, foreign-born parents did note that fresh-made products from their home countries are often bought pre-processed in the U.S. to save time, supporting research showing that time constraints and convenience are major drivers of food choice for recent immigrants.<sup>32</sup> It is important to note that aside from several differences in interpretation, such as home-prepared foods as "the healthiest," foreign-born and U.S.-born parents had similar views of processed foods. Simple messages, such as serving water instead of juice, were mentioned as well-received by both foreign and U.S.-born parents in the present study. Straightforward and easy-to-follow guidance about processed foods may have the most impact on parents' purchasing and feeding behaviors.

Our findings suggest several possible for avenues for communication and future areas of research regarding processed foods once common definitions are established. Parent reliance on children's tastes and preferences suggests that teaching children basic information about processed foods would provide support for parent-targeted communications. Some differences emerged by immigrant status, such as the perception among foreign-born parents that processed refers to "ready to eat," suggesting that cultural background and language should be carefully considered in designing messages. Barriers to serving healthful foods, such as time, budget and lack of nutrition knowledge have been widely investigated and should be considered when designing communication around processed foods.<sup>33</sup> Key stakeholders in children's health, such as family doctors,

nurses and school foodservice workers may be aware of the nuances of food processing and its potential negative and positive effects on dietary quality, and could function as trusted sources of information about processing. Further research regarding parents' primary sources of nutrition information is warranted.

This study explored parents' views on processed food, a topic that is central to understanding how this population approaches preparing food for their children. However, there are several notable limitations. Conclusions based on a low-income, ethnically diverse group of parents may not be generalizable to parents from other demographics. In addition, the foreign-born parents who participated in focus groups are not representative of all immigrant groups in the U.S., since there is considerable heterogeneity among this population. The use of voluntary participation during recruitment may have led to selection bias in the final sample, favoring parents who are more engaged in their child's food choices or are more knowledgeable about food and nutrition. Finally, focus groups were not segregated by gender or socioeconomic status, and it may be useful to understand how these characteristics influence perceptions and knowledge of food processing.

## **IMPLICATIONS**

The effects of processed food consumption on children's health is a rapidly growing area of research within the context of child obesity. The topic of food processing in terms of dietary guidance is novel, and may help to communicate information about healthier eating to caretakers. This study demonstrated that parents from diverse, urban school districts are familiar with some aspects of processing classification, but there are misperceptions about the association between processing level and healthfulness. Our results suggest that parents may benefit from a broader understanding of processed foods in terms of healthfulness and classification to inform better food choices for their families. However, without formal and consistent guidance regarding the role of processed foods in healthy diets, misunderstandings and gaps in knowledge will persist. A universally-accepted classification system for processed foods is necessary to establish effective communication regarding their association with healthfulness. Future research

should consider the best avenues for delivering information about processed foods to parents as well as other stakeholders.

## **ACKNOWLEDGEMENTS**

The Boston Nutrition Obesity Research Center generously contributed funding for this study. We would also like to encourage the work of two research assistants, Alejandra Cabrera, MS and Caitlin Bailey, MS, who contributed invaluable assistance in transcribing and coding data from this study.

## REFERENCES

1. MacInnis B, Rausser, G. Does processing contribute to child obesity disparities? *Amer J Agr Econ*. 2005;87(5):1154-1158.
2. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? *Am J Clin Nutr*. 2014;99(1):162-171.
3. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.
4. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2016;6(3):e009892.
5. Blondin S, AlSukait R, Bleiweiss-Sande R, Tanskey L, Wright CM, Goldberg J. Processed and Packed: what elementary school children bring for lunch. *Under Review*. 2019.
6. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-814.
7. Frederick CB, Snellman K, Putnam RD. Increasing socioeconomic disparities in adolescent obesity. *Proc Natl Acad Sci U S A*. 2014;111(4):1338-1342.
8. Kirkpatrick SI, Dodd KW, Reedy J, Krebs-Smith SM. Income and race/ethnicity are associated with adherence to food-based dietary guidance among US adults and children. *J Acad Nutr Diet*. 2012;112(5):624-635 e626.
9. Johnson D, Podrabsky M, Rocha A, Otten J. Effect of the Healthy Hunger-Free Kids Act on the Nutritional Quality of Meals Selected by Students and School Lunch Participation Rates. *JAMA Pediatr*. 2016;170:1.
10. van der Horst K, Oenema A, Ferreira I, et al. A systematic review of environmental correlates of obesity-related dietary behaviors in youth. *Health Educ Res*. 2007;22(2):203-226.
11. Wang L, Dalton WT, Schetzina KE, et al. Home Food Environment, Dietary Intake, and Weight among Overweight and Obese Children in Southern Appalachia. *Southern Medical Journal*. 2013;106(10):550-557.
12. Yee AZ, Lwin MO, Ho SS. The influence of parental practices on child promotive and preventive food consumption behaviors: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):47.
13. Hoover-Dempsey K, Walker J, Sandler H, et al. Why Do Parents Become Involved? Research Findings and Implications. *The Elementary School Journal*. 2005;106(2).
14. Daniel-White K. Reassessing Parent Involvement: Involving Language Minority Parents in School Work at Home. *Working Papers in Educational Linguistics*. 2002;18(1).
15. Kumanyika SK. Environmental influences on childhood obesity: ethnic and cultural influences in context. *Physiol Behav*. 2008;94(1):61-70.
16. Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? *Curr Obes Rep*. 2017;6(4):420-431.

17. Bielemann RM, Motta JVS, Minten GC, Horta BL, Gigante DP. Consumption of ultra-processed foods and their impact on the diet of young adults. *Revista de Saúde Pública*. 2015;49(0).
18. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients*. 2015;7(12):10076-10088.
19. Louzada ML, Baraldi LG, Steele EM, et al. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med*. 2015;81:9-15.
20. Moubarac JC, Parra DC, Cannon G, Monteiro CA. Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. *Curr Obes Rep*. 2014;3(2):256-272.
21. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003-2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S-2072S.
22. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly Processed and Ready-to-Eat Packaged Food and Beverage Purchases Differ by Race/Ethnicity among US Households. *J Nutr*. 2016;146(9):1722-1730.
23. Bleiweiss-Sande R, Goldberg J, Evans W, Chui K, Bailey C, Sacheck J. Chemicals, cans and factories: how children think about processed foods. *Under Review*. 2019.
24. Patton M. *Qualitative evaluation and research methods*. Newbury Park (CA): Sage Publications Inc; 1990.
25. *Pan American Health Organization Nutrient Profile Model*. Washington, DC: PAHO;2016.
26. Mozaffarian D, Ludwig, D. Dietary Guidelines in the 21st Century— a Time for Food. *JAMA*. 2010;304(6):681-682.
27. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada ML, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2017;1-13.
28. Dunford EK, Popkin BM. 37 year snacking trends for US children 1977-2014. *Pediatr Obes*. 2018;13(4):247-255.
29. Wang D, van der Horst K, Jacquier E, Eldridge AL. Snacking Among US Children: Patterns Differ by Time of Day. *J Nutr Educ Behav*. 2016;48(6):369-375 e361.
30. Popkin B, Urdy J. Adolescent Obesity Increases Significantly in Second and Third Generation U.S. Immigrants: The National Longitudinal Study of Adolescent Health. *J Nutr*. 1998;128(4):701-706.
31. Ayala GX, Baquero B, Klinger S. A systematic review of the relationship between acculturation and diet among Latinos in the United States: implications for future research. *J Am Diet Assoc*. 2008;108(8):1330-1344.
32. Oza-Frank R, Cunningham SA. The weight of US residence among immigrants: a systematic review. *Obes Rev*. 2010;11(4):271-280.

33. Patrick H, Nicklas T. A review of family and social determinants of children's eating patterns and diet quality. *J Am Coll Nutr.* 2005;24(2):83–92.

**Table 7.** Demographic characteristics, by immigrant status, of parents from three urban school districts participating in a focus group study on the topic of processed foods during Spring 2018 (N=37).

|                                                          | Foreign-born |        | U.S.-born |        | Total |         |
|----------------------------------------------------------|--------------|--------|-----------|--------|-------|---------|
| <b>Total sample, n (%)</b>                               | 23           | (62.2) | 14        | (37.8) | 37    | (100.0) |
| <b>Sex, n (%)</b>                                        |              |        |           |        |       |         |
| Female                                                   | 18           | (48.6) | 12        | (32.4) | 30    | (81.1)  |
| <b>Age (years), mean (sd)</b>                            | 41           | (5.4)  | 40        | (7.1)  | 40    | 5.9     |
| <b>Race/ethnicity, n (%)</b>                             |              |        |           |        |       |         |
| Non-Hispanic white                                       | 2            | (5.4)  | 6         | (16.2) | 8     | (21.6)  |
| Non-Hispanic black                                       | 6            | (16.2) | 3         | (8.1)  | 9     | (24.3)  |
| Hispanic                                                 | 11           | (29.7) | 3         | (8.1)  | 14    | (37.8)  |
| Multiracial/Asian/other                                  | 6            | (16.2) | 0         | -      | 6     | (16.2)  |
| <b>Child free/reduced price lunch eligibility, n (%)</b> |              |        |           |        |       |         |
| Yes                                                      | 21           | (56.8) | 5         | (13.5) | 26    | (70.3)  |
| <b>Education level, n (%)</b>                            |              |        |           |        |       |         |
| High school degree or less                               | 11           | (29.7) | 0         | -      | 11    | (29.7)  |
| Some college or associate's degree                       | 9            | (24.3) | 2         | (5.4)  | 11    | (29.7)  |
| Bachelor's degree or above                               | 5            | (13.5) | 10        | (27.0) | 15    | (40.5)  |

**Table 8.** Sample quotes and example foods to support participant's descriptions of terms related to processing, by immigrant status, from a focus group study of parents from three urban school districts on the topic of processed foods during Spring 2018 (N = 37).

| <b>Common/researcher definition</b>                                                                                                                                                                      | <b>Immigrant status</b> | <b>Representative quote</b>                                                                                              | <b>Common example foods given</b>                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| <b>Fresh food</b>                                                                                                                                                                                        |                         | <i><b>What does 'fresh food' mean?</b></i>                                                                               |                                                       |
| Generally used to describe food that has not been preserved; may also be used to describe unexpired foods, or just-cooked/prepared foods.                                                                | <i>Foreign-born</i>     | "Something that is cooked right away... Even if you open up a can of food, if you eat it right away, that is fresh." (M) | Homemade food, fruits and vegetables, organic food    |
|                                                                                                                                                                                                          | <i>U.S.-born</i>        | "Fruit and produce. Anything that's grown in the ground" (F)                                                             | Fruits and vegetables, organic food                   |
| <b>Man-made food</b>                                                                                                                                                                                     |                         | <i><b>What does 'man-made food' mean?</b></i>                                                                            |                                                       |
| Man-made food often refers to packaged or fast foods, as an antonym to 'nature-made.'                                                                                                                    | <i>Foreign-born</i>     | "I've heard of processed, but not man-made. Maybe someone cooking at home?" (F)                                          | Home-cooked foods, canned foods                       |
|                                                                                                                                                                                                          | <i>U.S.-born</i>        | "I think of processed, and quick and easy, like microwaved foods." (F)                                                   | Processed foods, microwaveable foods, unhealthy foods |
| <b>Machine-made food</b>                                                                                                                                                                                 |                         | <i><b>What does 'machine-made food' mean?</b></i>                                                                        |                                                       |
| Similar to man-made, machine-made is used to describe mass-produced, packaged foods.                                                                                                                     | <i>Foreign-born</i>     | "All the foods you keep in a freezer." (M)                                                                               | Chef Boyardee products, frozen pizza                  |
|                                                                                                                                                                                                          | <i>U.S.-born</i>        | "I think of processed foods... They're faster, but they're not good for you." (F)                                        | Hot dogs, canned foods                                |
| <b>Unprocessed food</b>                                                                                                                                                                                  |                         | <i><b>What does 'unprocessed food' mean?</b></i>                                                                         |                                                       |
| Single-ingredient foods with no or slight modifications that do not change inherent properties of the food as found in its natural form. <sup>20</sup>                                                   | <i>Foreign-born</i>     | "The foods that are not ready to eat... They need to be prepared." (M)                                                   | Uncooked foods, healthy foods, raw foods              |
|                                                                                                                                                                                                          | <i>U.S.-born</i>        | "Food that doesn't contain chemicals, or it's not in a box." (F)                                                         | Fruits and vegetables, raw foods                      |
| <b>Processed food</b>                                                                                                                                                                                    |                         | <i><b>What does 'processed food' mean?</b></i>                                                                           |                                                       |
| Highly-processed foods are multi-ingredient industrially formulated mixtures or dishes processed to the extent that they are no longer recognizable as their original plant/animal source. <sup>20</sup> | <i>Foreign-born</i>     | "Food that is cooked to the right temperature. It is ready to eat." (M)                                                  | Cooked foods, canned foods, unhealthy foods           |
|                                                                                                                                                                                                          | <i>U.S.-born</i>        | "Anything canned, boxed or bagged... quick and easy meals for the kids" (F)                                              | Deli meats, baked goods, frozen foods                 |

**Table 9.** Parent quotations to support classification of foods according to processing level, by theme from a focus group study of parents from three urban school districts on the topic of processed foods during Spring 2018 (N = 37).

| <b>Theme</b>                          | <b>Moderator: How would you put these foods into categories from least to most processed? Why?</b>                                                                                                                                                  |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Convenience/Preparation</i></b> | "The applesauce, juice and ketchup are the most processed, because you just open and they're ready to eat. Tomato sauce is the least because it's meant to be cooked again." (M, foreign-born)                                                      |
|                                       | "Things like the sauces - you can get them in cans if you need to be fast, or if you make it at home it's less processed." (F, foreign-born)                                                                                                        |
|                                       | "I think of the most processed things as just ready to go, like something you just pop in the microwave." (F, U.S.-born)                                                                                                                            |
| <b><i>Packaging</i></b>               | "Boxed, canned foods have to last much longer, so they're the most processed." (M, foreign-born)                                                                                                                                                    |
|                                       | "The apple and tomato are the least processed. When you open them and leave it in the refrigerator they go bad quickly. But the sauce, that's in a container so it stays good longer." (F, foreign-born)                                            |
|                                       | "I think the longer it seems to last, that seems to make it more highly processed. With ketchup it lasts a year or more in the bottle, whereas these ones (applesauce) aren't going to last as long in the plastic." (F, U.S.-born)                 |
| <b><i>Added ingredients</i></b>       | "I think the applesauce has just a few ingredients... so it's minimal processing compared to the other stuff." (F, U.S.-born)                                                                                                                       |
| Sugar                                 | "The ketchup usually has sugar added to it, so that makes it much more processed." (F, U.S.-born)                                                                                                                                                   |
| Salt                                  | "The applesauce might have salt added to it... you find salt in lots of processed foods." (F, U.S.-born)                                                                                                                                            |
| Chemicals                             | "These four [applesauce, tomato sauce, apple drink, ketchup] are all the same: very processed. They have to have chemicals to keep them fresh." (M, foreign-born)                                                                                   |
| <b><i>Healthfulness</i></b>           | "Unprocessed foods: they are the best for health." (M, foreign-born)                                                                                                                                                                                |
|                                       | "The tomato sauce because tomatoes are processed and then it's packed in a can. So they have lots of different kinds of chemicals in there to keep it fresh. So that's why I think this one is more processed, and less healthy." (F, foreign-born) |
|                                       | "Ketchup is too processed for health. I never buy that for my children. I don't buy canned foods." (F, foreign-born)                                                                                                                                |
|                                       | "I've always known juice has a lot of sugar. I don't let my kids drink much because I think of it as unhealthy." (F, U.S.-born)                                                                                                                     |

## CHAPTER VI: Associations between processed food consumption, dietary quality and weight status in a sample of low-income and ethnically diverse children

### Authors

Rachel Bleiweiss-Sande, MS<sup>1</sup>; Jennifer Sacheck, PhD<sup>2</sup>; Kenneth Chui, PhD, MPH<sup>1</sup>; Jeanne Goldberg, PhD, RD<sup>1</sup>; Caitlin Bailey, MS<sup>1</sup>; Erin Whitney Evans, PhD, RD<sup>3</sup>

<sup>1</sup>Friedman School of Nutrition Science and Policy, Tufts University

<sup>2</sup>Milken Institute School of Public Health, The George Washington University

<sup>3</sup>Warren Alpert Medical School, Brown University

### ABSTRACT

**Background.** Excess consumption of highly processed foods may be associated with lower diet quality and obesity prevalence, but few studies have examined these relationships in low-income children.

**Objective.** To evaluate the relationship between processed food consumption, diet quality as measured by the Healthy Eating Index-2015 (HEI-2015) and body mass index (BMI) in children.

**Design.** Cross-sectional analysis of baseline data from the Summer Food Service Program study.

**Participants/setting.** Children aged 6–12 years from low-income communities in the Northeastern U.S involved in a study assessing the impact of Summer Food Service participation on diet quality and weight status (N=131).

**Main outcome measures.** Total HEI-2015 score and percentage of calories consumed by processing level were computed per day from three 24-hour diet recalls. BMI was measured for calculation of BMI-z score.

**Statistical analyses performed.** Multivariable linear regression was used to assess the relationship between percentage of calories from foods by processing level (unprocessed and minimally, basic, moderately and highly processed), HEI-2015 and BMI-z score.

**Results.** The final sample was 58% male and 33.8% obese. Children consumed an average ( $\pm$  SD) of  $39.8 \pm 17.2\%$  of calories from highly-processed foods. Mean HEI-2015 score was  $49.9 \pm 13.4$  out of a 100-point maximum. A 10% increase in calories from highly-processed foods was associated with a 2.3 point decrease in total HEI-2015 score [95% CI (-3.0, -0.15)], and a 10% increase in calories from minimally processed foods was associated with a 3.0 increase in HEI-2015 score [95% CI (2.2, 3.8)] after controlling for relevant covariates. Relationships between processing level and BMIz score were not significant.

**Conclusions.** Among this cross-sectional sample of low-income children, greater intake of highly-processed foods was associated with lower dietary quality, but not obesity. Future research

should explore prospective associations between processed food consumption and weight status in children.

## BACKGROUND

Despite national efforts to address childhood obesity, recent estimates suggest that rates continue to rise among youth from low-income and racial/ethnic minority backgrounds.<sup>1</sup> Youth from low-income families are nearly twice as likely to be obese as their peers from higher income backgrounds.<sup>2</sup> A multitude of individual, family and social factors interact to contribute to this health disparity: these factors include poor diet, which often results from limited access to nutrient-dense foods, and an abundance of low-cost, energy-dense, processed foods.<sup>3,4</sup> Accordingly, highly processed food consumption has recently been suggested as a potential factor in the obesity epidemic, particularly among low-income children.<sup>5-8</sup>

According to the United States Department of Agriculture (USDA), food processing refers to any procedure that alters food from its natural state.<sup>9</sup> Thus, any food aside from raw, agricultural commodities is considered processed. Because of the considerable heterogeneity across processed foods, researchers have developed classification systems to distinguish foods according to the level or complexity of processing, ranging from minimally to highly processed.<sup>10-12</sup> One such system, which has been used globally to classify foods and beverages according to the degree of industrial processing,<sup>11</sup> was adapted by researchers at the University of North Carolina (UNC) to capture the complexity of the American food supply, classifying foods and beverages into four, mutually exclusive categories (**Table 1**).<sup>10</sup> The adapted system was found to have the highest inter-rater reliability among three processing classification systems used in the U.S. (Bleiweiss-Sande, under review).

Despite sophisticated classification systems, the effects of food processing on dietary quality remain controversial.<sup>13</sup> Processing can contribute important properties to foods, including enhanced safety, shelf life, and nutritional profiles in the case of fortified products.<sup>14,15</sup> However, it is not necessarily a good indicator of nutrient content. Two studies have reported wide variation in nutrient profiles of foods within processing level, suggesting that food choices guided solely on the principle of reducing highly-processed food intake could result in less nutrient-dense diets.<sup>10,12</sup> In contrast, findings from other studies demonstrate that highly processed foods are higher in saturated fat, added sugar and sodium compared to less-processed foods.<sup>10,16-18</sup> There is less research examining the relationship between processed food consumption and overall dietary quality, particularly in children. In one study of adults in the United Kingdom (UK), Adams et al. found that diets highest in minimally processed foods had

the most healthful nutritional profile, while those with the highest levels of highly-processed foods had the least healthful dietary profiles.<sup>19</sup> Similar results have been published based on evidence from Brazil,<sup>16</sup> Canada,<sup>7</sup> and the U.S.<sup>20</sup> There is also evidence that non-Hispanic black children have a lower intake of unprocessed or minimally processed foods compared to non-Hispanic white and white children,<sup>8</sup> and that non-Hispanic black households have lower overall purchases of highly processed foods, but that their purchases have higher energy density and lower nutrient quality compared to those of other ethnicities.<sup>21</sup> This suggests that prevalence of energy dense, highly processed food consumption may be greater among minority youth.

Similarly, there is limited and conflicting evidence on the association between processed food consumption and body weight. The same study by Adams et al. found an inverse association between overall intake of “processed culinary ingredients” (such as sugars and oils) and body weight, but no association specifically with intake of highly processed foods.<sup>19</sup> In contrast, two cross-sectional analyses of national data from the U.S. and Brazil found that higher intake of “ultra-processed” foods was associated with greater odds of being overweight or obese.<sup>22,23</sup> One systematic review surveyed available literature on the relationship between highly processed food consumption and body fat during childhood and adolescence.<sup>24</sup> Although most included studies showed a positive association, comparability between results was limited by lack of a standardized system for classifying processed foods, and most studies examined single foods (such as sugar-sweetened beverages) or group of foods (such as fast-foods) rather than using a measure of total diet.<sup>24</sup>

Given the continued rise in social inequalities in obesity among at-risk youth, additional research is warranted to understand these inconsistent findings in the context of children’s diets. To our knowledge, no study has examined the association between levels of processed food consumption and weight status among more vulnerable children. Furthermore, it is unknown whether dietary quality attenuates the positive relationship between highly processed food consumption and weight status that has been observed in some studies.<sup>22,23</sup> To address these gaps in the literature, the objective of this study was to investigate the independent associations between levels of processed food consumption, dietary quality and weight status and to examine the role of dietary quality as a mediator in the relationship between processed food intake and weight status in a low-income, ethnically diverse sample of children.

## METHODS

*Study population.* This study used baseline data from an observational study examining the role of the Summer Food Service Program on excess summer weight gain in children aged 6–12 years. Details of this study are described in detail elsewhere (Evans et al. Under Review). Briefly, 137 children were recruited from two low-income communities in the Northeast for participation during summer 2017 (n=67) or 2018 (n=70). Baseline assessments took place during May or June of 2017 and 2018. To be eligible, children, aged 6–12 years, had to qualify for free- or reduced-price school meals, be able to speak, read and write in English, have no extended travel plans for the summer, have informed consent to participate from a parent or caregiver, and provide informed assent if aged eight or older. Children were eligible to participate for one summer only. The study protocol was approved by the Institutional Review Board at The Miriam Hospital.

*Demographics.* Socio-demographic characteristics were collected at baseline visits via parent/caregiver-completed questionnaire on child date of birth, sex, race/ethnicity, National School Breakfast Program (SBP) and National School Lunch Program (NSLP) participation, and maternal education.

*Anthropometrics.* Trained research assistants measured height and weight, in triplicate, at baseline. Child weight was measured in street clothes, without shoes, to the nearest 0.1 kilogram using a calibrated digital scale (Tanita BWB 800; Tanita Corporation of America, Inc., Arlington Heights, IL, USA). Height was measured to the nearest millimeter using a portable stadiometer (Model 214, Seca Weighing and Measuring Systems, Handover, MD). BMI-for-age percentile and BMI-for-age z-scores (BMIZ) were calculated based on the Centers for Disease Control and Prevention (CDC) standards,<sup>25</sup> and weight categories were defined according to CDC cutpoints.<sup>26</sup>

*Dietary assessment.* Diet was assessed at baseline via three 24-hour dietary recalls collected on non-consecutive days, including two weekdays and one weekend day. Trained research staff conducted the interviews via telephone in English or Spanish using Nutrition Data Systems for Research (NDSR, software version 2018, University of Minnesota, Minneapolis, MN). NDSR uses a multiple pass methodology to collect detailed information on each food and beverage item consumed by eating occasion over the past 24-hour period.<sup>27</sup> For children under ten years, recalls were completed with by a parent or caretaker with assistance from the child,

while children ten years and older completed interviews on their own with input from the parent/caregiver as needed.

To assess dietary quality, Healthy Eating Index 2015 (HEI-2015) scores were calculated.<sup>28</sup> The HEI-2015 includes thirteen components that reflect the key recommendations in the 2015-2020 Dietary Guidelines for Americans (DGA).<sup>29</sup> Component scores are summed to calculate a total HEI-2015 based on a scale from 0-100, with higher scores reflective of better adherence to the DGA and resulting higher dietary quality. HEI-2015 scores were analyzed by day, rather than averaged across participant, to retain information concerning differences in dietary quality on weekends compared to weekdays.

*Classification of foods based on degree of processing.* Food items were coded according to the extent and purpose of industrial processing using methods outlined by Poti et al. (**Table 10**),<sup>10</sup> a framework that was found to have the highest inter-rater reliability among processing classification systems used in the U.S. (Bleiweiss-Sande et al., Under review). According to this classification system, “unprocessed and minimally processed” foods (UPF) are single-ingredient products with no or slight modification; “basic processed” foods (BPF) include single food components for use in cooking or items processed for preservation without added ingredients; “moderately processed” foods (MPF) are described as UPFs or BPFs with the addition of flavor additives or 100% whole grain products with no added sweeteners or fats and, “highly processed” foods (HPF) are multi-ingredient industrially formulated mixtures, including stand-alone products as well as condiments and sauces.<sup>10</sup>

Foods were coded using the NDSR ingredients file (output file 1), which disaggregates foods into constituent ingredients where possible (e.g. an assembled turkey sandwich would consist of whole grain bread, turkey, lettuce, mustard and mayonnaise, with each ingredient coded separately). In some cases, the ingredients for industrially-produced products included items such as “water, lost in evaporation process” and “water, used in commercial manufacturing.” These items occurred in small or negative gram amounts, so were dropped from the sample (n=302). A total of 9,070 foods were used in analyses.

All foods were coded independently by two researchers (author 1 and 5), and discrepancies were discussed until a consensus was reached. Processing level was operationalized as percentage of calories from each processing level (UPF, BPF, MPF or HPF) per day of recall.

*Analysis.* All analyses were performed using SAS 9.4 (SAS Inc, Cary, NC) and Stata Statistical Software Stata/IC 15.1 (StataCorp, College Station, TX). Dietary quality, as measured by the HEI-2015 was analyzed using SAS code developed by NDSR.<sup>30</sup> Univariate statistics were used to describe the sample. To assess the relationship between processed food intake and BMIz score, multivariate linear regression was used with percentage of calories from UPF, BPF, MPF and HPF as explanatory variables in separate models. To account for intra-child correlations between food recall days, the analysis was recast as a survey by designating each child as a primary sampling unit and each day of recall as a case. This approach allows the dependent variable (BMIz) to remain constant in each cluster, while also allowing us to account for differences in dietary intake patterns on week vs. weekend days. To maintain consistency between models, this method was also used to examine the relationship between processed food consumption and HEI-2015 score. Previous literature points to differences in weekday versus weekend eating patterns.<sup>31-33</sup> To account for this, 24-hour recalls were weighted by day of the week, such that weekdays were assigned a weight of five out of seven, and weekends were assigned a weight of two out seven. According to the study protocol, most cases provided data on two weekdays and one weekend, such that the three record weights would have a ratio of 2.5:2.5:2.0. Sensitivity analyses comparing the results of a repeated measures approach to the survey weights approach and day of week vs. equal weighting are presented in **Appendix C.1 and C.2**, respectively.

A priori, we hypothesized a positive association between processing level and BMIz in this sample. Therefore, we sought to determine whether HEI-2015 mediated the relationship between processed food intake and BMIz score using structural equation modelling, retaining the same survey weights and cluster identification as described above. All models were adjusted for age, sex, race/ethnicity, SBP and NSLP participation and maternal education where appropriate.

## RESULTS

Children with incomplete demographic, anthropometric or dietary data were dropped from the analysis (n=6) for a final sample size of 131 (mean age = 9.3 years, SD = 1.9; 58% male). The majority were Hispanic (73%), eligible for free versus reduced-price school meals (92%), and had a mother with an education level of high school or less (59%). A little under half of children (43%) had overweight or obesity (**Table 11**). As shown in **Table 12**, the overall mean

HEI-2015 score was 49.9 out of 100 (SD  $\pm$  13.4). Mean HEI-2015 score was higher during the week [51.5, 95% CI (49.8, 53.2)] compared to weekends [46.5, 95% CI (44.4, 48.7)]. The majority of children's energy was derived from HPF (39.8%) followed by UPF (27.7%). The percentage of calories from foods by processing level did not vary significantly between weekdays and weekend.

*Relationship between percentage of calories by processing level and HEI-2015.* Results of unadjusted and adjusted linear regression models for the association between percentage of calories from processing level and HEI-2015 score are presented in **Table 13**. After controlling for maternal education and participation in school meals, a 10% point increase in energy from HPF was associated with a 2.0 (95% CI: -2.7, -1.2) point decrease in HEI-2015 score. In contrast, a 10% increase in energy from UPF was associated with a 2.9 (95% CI: 2.1, 3.8) point increase in HEI-2015 score in the adjusted model. Associations between basic and moderately processed foods and HEI-2015 score were not statistically significant. Assigning equal weight to weekday and weekend recall days equally did not produce significantly different results, indicating that the associations between HEI and percent calories are likely similar between week and weekend days.

*Relationship between percentage of calories by processing level and BMIz.* Results of unadjusted and adjusted linear regression models for the association between percentage of calories from processing level and BMIz score are presented in **Table 14**. After adjusting for sex, SBP and NSLP participation, there was no significant relationship between percentage of calories consumed by processing level and BMIz score. Assigning equal weight to weekday and weekend recall days equally did not produce significantly different results.

*Assessment of HEI-2015 as a mediator in the relationship between processed food intake and BMIz.* Given the null relationship between percent of energy intake by processing level and BMIz score, an in-depth analysis of HEI-2015 as a mediator in this relationship was rendered irrelevant and hence is not shown. Results of the mediation analyses performed are presented in **Appendix C.3**.

## DISCUSSION

This analysis using dietary data collected from a low-income, ethnically diverse sample of children shows that greater intake of HPFs is associated with lower dietary quality while a

greater intake of UPFs has a positive association with dietary quality. Together, these results offer insight into complementary approaches for improving dietary quality in child populations, through reducing HPF availability and consumption and/or encouraging UPF consumption. In our cross-sectional study design, we did not identify a significant relationship between processed food intake and weight status. To our knowledge, this is the first study to examine associations between consumption of foods from all processing levels, dietary quality and weight status in a sample of children from low-income backgrounds.

Our results suggest that that majority of energy consumed by this population was derived from HPFs, with children consuming roughly 40% of energy from the highest processing category. This estimate is similar to one based on child dietary intake data from the National Health and Nutrition Examination Survey (NHANES) 2003-2008 by Eicher-Miller et al., which found that ready-to-eat-processed foods contributed 34.8% of daily energy intake.<sup>8</sup> Our results also support that 27.7% of daily energy intake was derived from UPFs, compared to 13.3% in the study by Eicher-Miller et al. Comparability between studies is somewhat limited by the fact that we used a different system for classifying processed foods, and given that our sample was youth from predominately low-income and minority backgrounds. However, they do suggest that UPF consumption has increased over the past decade while that of HPF has remained stable. This is supported by a report from the Pan American Health Organization, which shows that while North America is the highest consumer of HPFs globally, growth between 2000-2013 was minimal (2.3%) in the US as compared to global averages (43.7%) .<sup>34</sup> This substantial increase is largely due to growth in middle and lower-income countries.

Consistent with the results from this study, related research has demonstrated an inverse association between highly processed food consumption and dietary quality. A study of national food purchase data from 2000-2012 in the U.S. found that households were more likely to exceed recommendations for saturated fat, sugar and salt intake for HPF compared to less-processed food purchases,<sup>10</sup> while an analysis of NHANES dietary recalls showed an association between HPF and consumption of added sugars.<sup>17</sup> Evidence from Columbia<sup>35</sup> and Brazil<sup>36</sup> has demonstrated lower nutritional profiles among children and young adults, respectively, who ate higher amounts of HPFs. Using national food consumption data, a more recent study from Brazil showed a direct association between highly processed food consumption and an unhealthful dietary pattern.<sup>16</sup> Extensive evidence demonstrates that children from lower socio-economic

status backgrounds have lower diet quality, which may increase the risk of adverse health outcomes during childhood or later in life.<sup>37-39</sup> Together with the research mentioned above, our findings support the conclusion that limiting highly processed foods in children's diets will improve overall dietary quality.

Our analysis does not support an association between processed food consumption and BMIz in children, a finding that is not unique. A study of UK adults found an inverse association between HPF consumption and dietary quality, but not obesity.<sup>19</sup> Similarly, a longitudinal analysis of 1035 adolescents from Brazil found that those in the top quartile of HPF consumed had lower intake of fruits and vegetables, as well as a lower BMIz at baseline and follow-up.<sup>40</sup> Children in the top quartile of HPF consumption also had higher physical activity levels, which may help to explain these unexpected relationships.<sup>40</sup> The authors suggest that obesity may be more closely related to quantity rather than quality of food consumption; this hypothesis is supported by interventions that found no change in obesity when high energy-dense foods are displaced by fruits and vegetables.<sup>41,42</sup>

In contrast, a small body of evidence from Brazil and Sweden suggests that over-consumption of highly processed foods may be associated with obesity in both adults<sup>22,23,43,44</sup> and children.<sup>22,43</sup> Further evidence points to an association between highly processed food intake, cardiovascular disease<sup>45-47</sup> and metabolic syndrome in children,<sup>48</sup> conditions that are often associated with obesity. Related research has examined associations between specific food groups considered to be HPFs, finding positive associations between sugar-sweetened beverages,<sup>49,50</sup> a Western dietary pattern and excess body weight.<sup>51</sup> However, scholars note that there is limited research investigating each of these outcomes, and the majority of studies are cross-sectional in design.<sup>52</sup> One prospective study of HPF consumption and risk of overweight and obesity in a middle-aged Spanish cohort found that the highest HPF consumers were at a greater risk of overweight and obesity.<sup>53</sup> This study was limited by use of a food frequency questionnaire that asked about 136 commonly-consumed HPFs, rather than a measure of total diet, and a study sample consisting of university graduates that may not be generalizable to other populations.

Researchers have hypothesized that HPF consumption impacts body weight by increasing added sugars, fats and total calorie intake, and displacing foods high in fiber, protein and micronutrients.<sup>5,53,54</sup> Others have posited that convenience is a key factor in promoting excess

consumption of certain HPFs.<sup>10,55</sup> An examination of household HPFs and convenience products by race/ethnicity demonstrated that compared to non-Hispanic white households, non-Hispanic black and Hispanic households had lower purchases of HPFs and convenience purchases, but non-Hispanic blacks had higher purchases of sugar-sweetened beverages.<sup>21</sup> A related study found that non-Hispanic blacks and Hispanics had lower intakes of HPFs compared to non-Hispanic whites in a cross-sectional analysis of NHANES 2003-2008 data.<sup>8</sup> These results suggest that factors beyond processing and convenience, such as home cooking and preparation methods, should be considered in examining racial/ethnic disparities in dietary quality and obesity.<sup>21</sup>

The relative homogeneity of the present study's population may also play a role in the observed non-significant results concerning processed food intake and obesity. First, over 92% of the sample qualified for free school meals, a measure of household economic status, and the entire sample was eligible for either free or reduced-price lunch by design. Low-income neighborhoods tend to have a higher concentration of convenience stores and fast food restaurants, which sell energy-dense, nutrient poor foods, and limited access to supermarkets.<sup>56</sup> Thus, families in low-socioeconomic status neighborhoods may be more likely to buy highly refined, energy-dense foods due to issues of food access as well as cost.<sup>39</sup> This is supported by the fact that the average HEI-2015 total score in our sample was 49.9 out of a possible 100. Second, the prevalence of overweight and obesity in this sample was higher than national averages. Specifically, 33.8% of youth had obesity, compared to 18.5% nationally, and other 9.2% had overweight. Evidence supports that under-reporting is more frequent among individuals with overweight and obesity,<sup>57,58</sup> such that associations between self-reported dietary intake and weight status may be biased.<sup>59</sup> Accordingly, a similar analysis should be done in a nationally representative sample with more heterogeneity with respect to socioeconomic and weight status.

This study has several limitations to consider. The study sample was composed of children from predominantly racial/ethnic minority and low-income backgrounds, and findings may not be generalizable to other populations in the U.S. As mentioned above, self-reported dietary data is subject to social desirability bias among others, which may lead to higher reported intakes of healthful foods and lower intakes of unhealthful foods, potentially underestimating the proportion of highly processed foods consumed. However, 24-hour recalls are the gold-standard for self-report dietary data collection, and our estimate of highly processed food consumption in

this population was comparable to results from similar studies.<sup>10,20</sup> It is important to tailor study designs to processing level as the outcome of interest during all stages of the data collection process, such as ensuring that interviews request product brand names, information on flavorings and other additions, as well as establishing consistent methods for recording food items.

The main strengths of this study include use of 24-hr recalls for collecting dietary measures and objective measures for height and weight. The study is also strengthened by inclusion of a low-income and ethnic/minority youth sample, as this population is at the greatest risk of consuming highly processed diets and represents a particular challenge for collecting detailed dietary data.<sup>39,60</sup> Through use of NDSR, we were able to analyze foods based on their constituent ingredients, reducing potential for misclassification of the processing level of foods. While most analyses examining processed food consumption and obesity have utilized nationally representative datasets, this study looked specifically at a population of lower income, racial/ethnic minority children who are at a greater risk of obesity and associated health conditions.

## **CONCLUSIONS**

This study contributes important findings concerning the role of processed foods in the diets of children from racially/ethnically diverse and lower-income backgrounds. Our findings demonstrate that greater intakes of highly processed foods are associated with lower dietary quality, while increased consumption of unprocessed or minimally processed food is associated with higher dietary quality. Our findings do not support an association between processed food consumption and weight status. However, future research should clarify these results through prospective study designs in similar populations.

## REFERENCES

1. Hales C, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2017;288.
2. Ogden CL, Carroll MD, Fakhouri TH, et al. Prevalence of Obesity Among Youths by Household Income and Education Level of Head of Household — United States 2011–2014. *MMWR Morb Mortal Wkly Rep* 2018;67:186–189.
3. Ambrosini GL. Childhood dietary patterns and later obesity: a review of the evidence. *Proc Nutr Soc*. 2014;73(1):137-146.
4. Poti JM, Slining MM, Popkin BM. Where are kids getting their empty calories? Stores, schools, and fast-food restaurants each played an important role in empty calorie intake among US children during 2009–2010. *J Acad Nutr Diet*. 2014;114(6):908-917.
5. Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutr*. 2009;12(5):729-731.
6. Monteiro CA, Levy RB, Claro RM, de Castro IR, Cannon G. Increasing consumption of ultra-processed foods and likely impact on human health: evidence from Brazil. *Public Health Nutr*. 2011;14(1):5-13.
7. Moubarac JC, Martins AP, Claro RM, Levy RB, Cannon G, Monteiro CA. Consumption of ultra-processed foods and likely impact on human health. Evidence from Canada. *Public Health Nutr*. 2013;16(12):2240-2248.
8. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients*. 2015;7(12):10076-10088.
9. Chapter 9—Federal Food, Drug, and Cosmetic Act. In. *Title 21—Food and Drugs*. Vol 21: US Food and Drug Administration, Department of Health and Human Services; 2016.
10. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251-1262.
11. Monteiro C, Levy R, Claro R, Ribeiro de Castro I, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11).
12. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003–2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S-2072S.
13. Gibney MJ, Forde CG, Mullally D, Gibney ER. Ultra-processed foods in human health: a critical appraisal. *Am J Clin Nutr*. 2017;106:717-724.
14. Dwyer JT, Fulgoni VL, 3rd, Clemens RA, Schmidt DB, Freedman MR. Is "processed" a four-letter word? The role of processed foods in achieving dietary guidelines and nutrient recommendations. *Adv Nutr*. 2012;3(4):536-548.
15. Weaver CM, Dwyer J, Fulgoni VL, et al. Processed foods: contributions to nutrition. *The American Journal of Clinical Nutrition*. 2014;99(6):1525-1542.

16. Louzada M, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr.* 2017;1-9.
17. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open.* 2016;6(3):e009892.
18. Albuquerque TG, Santos J, Silva MA, Oliveira M, Costa HS. An update on processed foods: Relationship between salt, saturated and trans fatty acids contents. *Food Chem.* 2018;267:75-82.
19. Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *Int J Behav Nutr Phys Act.* 2015;12:160.
20. Martinez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. *Popul Health Metr.* 2017;15(1):6.
21. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly Processed and Ready-to-Eat Packaged Food and Beverage Purchases Differ by Race/Ethnicity among US Households. *J Nutr.* 2016;146(9):1722-1730.
22. Louzada ML, Baraldi LG, Steele EM, et al. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med.* 2015;81:9-15.
23. Juul F, Martinez-Steele E, Parekh N, Monteiro CA, Chang VW. Ultra-processed food consumption and excess weight among US adults. *Br J Nutr.* 2018;120(1):90-100.
24. Costa CS, Del-Ponte B, Assuncao MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr.* 2017;1-12.
25. Kuczmarski R, Ogden C, Guo S, et al. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat.* 2002;11(246):1-190.
26. *CDC Growth Charts: United States.* Centers for Disease Control and Prevention, National Center for Health Statistics;2000.
27. Feskanich D, Sielaff B, Chong K, Bartsch G. Computerized collection and analysis of dietary intake information. *Comput Methods Programs Biomed.* 1989;30:47-57.
28. Krebs-Smith SM, Pannucci TE, Subar AF, et al. Update of the Healthy Eating Index: HEI-2015. *J Acad Nutr Diet.* 2018;118(9):1591-1602.
29. *2015–2020 Dietary Guidelines for Americans. 8th Edition.* Available at <http://health.gov/dietaryguidelines/2015/guidelines/>. U.S. Department of Health and Human Services and U.S. Department of Agriculture;December 2015.
30. Healthy Eating Index. Nutritional Coordinating Center, University of Minnesota. <http://www.ncc.umn.edu/healthy-eating-index-hei/>. Published 2018. Accessed November 15, 2018.
31. Haines PS, Hama MY, Guilkey DK, Popkin B. Weekend Eating in the United States Is Linked with Greater Energy, Fat, and Alcohol Intake. *Obesity Research.* 2003;11(8).
32. Hanson KL, Olson CM. School meals participation and weekday dietary quality were associated after controlling for weekend eating among U.S. school children aged 6 to 17 years. *J Nutr.* 2013;143(5):714-721.

33. Hart CN, Raynor HA, Osterholt KM, Jelalian E, Wing RR. Eating and activity habits of overweight children on weekdays and weekends. *Int J Pediatr Obes.* 2011;6(5-6):467-472.
34. *Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications.* Washington, DC: Pan American Health Organization;2015.
35. Cornwell B, Villamor E, Mora-Plazas M, Marin C, Monteiro CA, Baylin A. Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. *Public Health Nutr.* 2017;1-6.
36. Bielemann RM, Motta JVS, Minten GC, Horta BL, Gigante DP. Consumption of ultra-processed foods and their impact on the diet of young adults. *Revista de Saúde Pública.* 2015;49(0).
37. Fahlman MM, McCaughy N, Martin J, Shen B. Racial and socioeconomic disparities in nutrition behaviors: targeted interventions needed. *J Nutr Educ Behav.* 2010;42(1):10-16.
38. Kirkpatrick SI, Dodd KW, Reedy J, Krebs-Smith SM. Income and race/ethnicity are associated with adherence to food-based dietary guidance among US adults and children. *J Acad Nutr Diet.* 2012;112(5):624-635 e626.
39. Ranjit N, Wilkinson AV, Lytle LM, Evans AE, Saxton D, Hoelscher DM. Socioeconomic inequalities in children's diet: the role of the home food environment. *Int J Behav Nutr Phys Act.* 2015;12 Suppl 1:S4.
40. Cunha DB, da Costa THM, da Veiga GV, Pereira RA, Sichieri R. Ultra-processed food consumption and adiposity trajectories in a Brazilian cohort of adolescents: ELANA study. *Nutr Diabetes.* 2018;8(1):28.
41. Kaiser KA, Brown AW, Bohan Brown MM, Shikany JM, Mattes RD, Allison DB. Increased fruit and vegetable intake has no discernible effect on weight loss: a systematic review and meta-analysis. *Am J Clin Nutr.* 2014;100(2):567-576.
42. Bayer O, Nehring I, Bolte G, von Kries R. Fruit and vegetable consumption and BMI change in primary school-age children: a cohort study. *Eur J Clin Nutr.* 2014;68(2):265-270.
43. Canella DS, Levy RB, Martins AP, et al. Ultra-processed food products and obesity in Brazilian households (2008-2009). *PloS one.* 2014;9(3):e92752.
44. Silva FM, Giatti L, de Figueiredo RC, et al. Consumption of ultra-processed food and obesity: cross sectional results from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) cohort (2008-2010). *Public Health Nutr.* 2018;21(12):2271-2279.
45. Appannah G, Pot GK, Huang RC, et al. Identification of a dietary pattern associated with greater cardiometabolic risk in adolescence. *Nutr Metab Cardiovasc Dis.* 2015;25(7):643-650.
46. Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. *Nutr Metab Cardiovasc Dis.* 2015;25(1):116-122.
47. Vitolo MR, Rauber F. Influence of Food Processing on Blood Lipids in Children. *Nutrients.* 2016;8(2):97.
48. Tavares LF, Fonseca SC, Garcia Rosa ML, Yokoo EM. Relationship between ultra-processed foods and metabolic syndrome in adolescents from a Brazilian Family Doctor Program. *Public Health Nutr.* 2012;15(1):82-87.

49. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *The American Journal of Clinical Nutrition*. 2013;98(4):1084-1102.
50. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA. Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Pediatrics*. 2013;131(1):14-21.
51. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? *Am J Clin Nutr*. 2014;99(1):162-171.
52. Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? *Curr Obes Rep*. 2017;6(4):420-431.
53. Mendonca RD, Pimenta AM, Gea A, et al. Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr*. 2016;104(5):1433-1440.
54. Fardet A, Rock E, Bassama J, et al. Current food classifications in epidemiological studies do not enable solid nutritional recommendations for preventing diet-related chronic diseases: the impact of food processing. *Adv Nutr*. 2015;6(6):629-638.
55. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada ML, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2017:1-13.
56. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med*. 2009;36(1):74-81.
57. Yamaguchi M, Steeves E, Shipley C, Hopkins L, Cheskin L, Gittelsohn J. Inconsistency between Self-Reported Energy Intake and Body Mass Index among Urban, African-American Children. *PloS one*. 2016;11(12).
58. Suissa K, Benedetti A, Henderson M, Gray-Donald K, Paradis G. The Cardiometabolic Risk Profile of Underreporters of Energy Intake Differs from That of Adequate Reporters among Children at Risk of Obesity. *The Journal of Nutrition*. 2019;149(1):123-130.
59. Subar A, Freedman L, Tooze J, et al. Addressing Current Criticism Regarding the Value of Self-Report Dietary Data. *The Journal of Nutrition*. 2015;145(12):2639-2645.
60. Singh GK, Siahpush M, Kogan MD. Rising social inequalities in US childhood obesity, 2003-2007. *Ann Epidemiol*. 2010;20(1):40-52.

**Table 10.** Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing<sup>9</sup>

| Category/definition                                                                                                                                                                                                                | Examples                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Unprocessed &amp; minimally processed foods</b>                                                                                                                                                                                 |                                                                                                                                                                         |
| Single-ingredient foods with no or very slight modifications that do not change inherent properties of the food as found in its natural form.                                                                                      | Plain milk; fresh, frozen or dried plain fruit or vegetables; eggs, unseasoned meat; whole grain flour and pasta; brown rice; honey, herbs and spices.                  |
| <b>Basic processed foods</b>                                                                                                                                                                                                       |                                                                                                                                                                         |
| <i>Processed basic ingredients:</i> single isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food.                                       | Unsweetened fruit juice not from concentrate; whole grain pasta; oil, unsalted butter, sugar, salt.                                                                     |
| <i>Processed for basic preservation or precooking:</i> single minimally processed foods modified by physical or chemical processes for the purpose of preservation or precooking but remaining as single foods.                    | Unsweetened fruit juice from concentrate; unsweetened/unflavored canned fruit, vegetables, legumes; plain peanut butter, refined grain pasta, white rice; plain yogurt. |
| <b>Moderately processed foods</b>                                                                                                                                                                                                  |                                                                                                                                                                         |
| <i>Moderately processed for flavor:</i> single minimally or moderately processed foods with addition of flavor additives for the purpose of enhancing flavor; directly recognizable as original plant/ animal source.              | Sweetened fruit juice, flavored milk; frozen French fries; salted peanut butter; smoked or cure meats; cheese, flavored yogurt, salted butter.                          |
| <i>Moderately processed grain products:</i> grain products made from whole-grain flour with water, salt, and/or yeast.                                                                                                             | Whole grain breads, tortillas or crackers with no added sugar or fat.                                                                                                   |
| <b>Highly processed foods</b>                                                                                                                                                                                                      |                                                                                                                                                                         |
| <i>Highly processed ingredients:</i> multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and consumed as additions.               | Tomato sauce, salsa, mayonnaise, salad dressing, ketchup.                                                                                                               |
| <i>Highly processed stand-alone:</i> multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and not typically consumed as additions. | Soda, fruit drinks; frozen vegetable dishes with sauce; formed lunchmeats; breads made with refined flours; pastries; ice-cream, processed cheese; candy.               |

**Table 11.** Demographic characteristics, children participating in the Summer Food Service Study (N=131)

|                                                   |     |        |
|---------------------------------------------------|-----|--------|
| Sex, n (%)                                        |     |        |
| Male                                              | 76  | (58.0) |
| Female                                            | 60  | (45.8) |
| Age (years), mean (sd)                            | 9.3 | (1.90) |
| Race, n (%)                                       |     |        |
| Non-Hispanic black                                | 10  | (7.6)  |
| Non-Hispanic white                                | 6   | (4.6)  |
| Hispanic                                          | 95  | (72.5) |
| Multiracial/Asian/other                           | 20  | (15.3) |
| Child free/reduced price lunch eligibility, n (%) |     |        |
| Free                                              | 121 | (92.4) |
| Reduced                                           | 10  | (7.6)  |
| Mother's education level, n (%)                   |     |        |
| High school degree or less                        | 77  | (58.8) |
| Some college or associate's degree                | 32  | (24.4) |
| College degree or above                           | 27  | (20.6) |
| Weight status, n (%)                              |     |        |
| Underweight <sup>a</sup>                          | 0   | 0.0    |
| Normal weight <sup>b</sup>                        | 75  | (57.3) |
| Overweight <sup>c</sup>                           | 12  | (9.2)  |
| Obese <sup>d</sup>                                | 44  | (33.8) |

<sup>a</sup> BMI-for-age percentile < 5<sup>th</sup>

<sup>b</sup> BMI-for-age percentile  $\geq$  5<sup>th</sup> and < 85<sup>th</sup>

<sup>c</sup> BMI-for-age percentile  $\geq$  85<sup>th</sup> and < 95<sup>th</sup>

<sup>d</sup> BMI-for-age percentile  $\geq$  95<sup>th</sup>

**Table 12.** Dietary characteristics by weekday vs. weekend, children participating in the Summer Food Service Study (N=131)

|                                                                            | Overall |         | Weekdays |       |      | Weekends |       |      |
|----------------------------------------------------------------------------|---------|---------|----------|-------|------|----------|-------|------|
| Daily energy intake (kcal), mean (SD or $\pm$ SE)                          | 1,411.2 | (539.9) | 1,391.1  | $\pm$ | 32.7 | 1,454.9  | $\pm$ | 54.2 |
| Health Eating Index 2015, mean (SD or $\pm$ SE)                            | 49.9    | (13.4)  | 51.5*    | $\pm$ | 0.9  | 46.5*    | $\pm$ | 1.1  |
| Percentage of kcal by processing level, mean (SD or $\pm$ SE) <sup>a</sup> |         |         |          |       |      |          |       |      |
| Unprocessed/minimally                                                      | 27.7    | (15.2)  | 28.1     | $\pm$ | 0.9  | 26.6     | $\pm$ | 1.5  |
| Basic processed                                                            | 16.7    | (13.2)  | 16.1     | $\pm$ | 0.8  | 18.0     | $\pm$ | 1.3  |
| Moderately                                                                 | 15.8    | (13.4)  | 16.5     | $\pm$ | 0.8  | 14.4     | $\pm$ | 1.2  |
| Highly                                                                     | 39.8    | (17.2)  | 39.2     | $\pm$ | 1.1  | 40.9     | $\pm$ | 1.5  |

<sup>a</sup>As defined in Poti et al. (2015)<sup>9</sup>\*Mean Healthy Eating Index score was significantly different on weekdays compared to weekends,  $p < 0.001$  ( $t$  test).

**Table 13.** Results of linear regression models quantifying the relationship between percent of calories from processing level<sup>9</sup> per intake day<sup>a</sup> with Healthy Eating Index 2015 score among children participating in the Summer Foodservice Study (N=131)

|             | Unadjusted |        |        |          | Adjusted <sup>b</sup> |        |        |          |
|-------------|------------|--------|--------|----------|-----------------------|--------|--------|----------|
|             | $\beta$    | 95% CI |        | <i>p</i> | $\beta$               | 95% CI |        | <i>p</i> |
| Unprocessed | *0.307     | 0.223  | 0.390  | 0.00     | *0.297                | 0.211  | 0.383  | 0.00     |
| Basic       | 0.031      | -0.098 | 0.161  | 0.63     | 0.002                 | -0.100 | 0.104  | 0.97     |
| Moderately  | -0.059     | -0.189 | 0.070  | 0.37     | -0.066                | -0.187 | 0.054  | 0.40     |
| Highly      | *-0.226    | -0.300 | -0.152 | 0.00     | *-0.196               | -0.269 | -0.122 | 0.00     |

<sup>a</sup> Consumption data from three, non-consecutive 24-hr recalls, weighted by weekday vs. weekend

<sup>b</sup> Adjusted for maternal education level and days of National School Breakfast and National School Lunch Program participation.

\* Significant association,  $p < 0.001$

**Table 14.** Results of linear regression models quantifying the relationship between percent of calories from processing level<sup>9</sup> per intake day<sup>a</sup> with age- and sex-standardized body mass index score among children participating in the Summer Foodservice Study (N=131)

|                       | Unadjusted |        |       |          | Adjusted <sup>b</sup> |        |       |          |
|-----------------------|------------|--------|-------|----------|-----------------------|--------|-------|----------|
|                       | $\beta$    | 95% CI |       | <i>p</i> | $\beta$               | 95% CI |       | <i>p</i> |
| Unprocessed/minimally | 0.005      | -0.005 | 0.015 | 0.31     | 0.007                 | -0.002 | 0.016 | 0.13     |
| Basic                 | 0.000      | -0.010 | 0.009 | 0.99     | -0.003                | -0.012 | 0.005 | 0.43     |
| Moderately            | -0.005     | -0.015 | 0.005 | 0.34     | -0.007                | -0.016 | 0.002 | 0.13     |
| Highly                | -0.001     | -0.011 | 0.008 | 0.80     | 0.001                 | -0.007 | 0.008 | 0.87     |

<sup>a</sup> Consumption data from three, non-consecutive 24-hr recalls, weighted by weekday vs. weekend

<sup>b</sup> Adjusted for sex, days of National School Breakfast and National School Lunch Program participation.

## **CHAPTER VII: SUMMARY & DISCUSSION**

### **Introduction**

Recent estimates show that efforts to curb the progression of childhood obesity have had some successes, yet the prevalence among low-income and ethnically diverse children remains elevated.<sup>1,2</sup> Poor diet, as a key component of the energy balance equation, is an important target for obesity prevention, particularly among youth from low-SES households.<sup>3</sup> However, communicating evidence-based actionable messages about healthful eating remains a challenge.<sup>4</sup> Within this context, food processing has emerged as a potential factor in childhood obesity. To define its possible role in childhood obesity and to incorporate communication about processed food into efforts to promote healthy diets requires consistent definitions to categorize foods according to the degree to which they have been processed. While classification systems have been adopted globally as a novel approach to studying obesity and diet-related health conditions,<sup>5</sup> and for promoting healthful eating to address the ongoing obesity epidemic, it can be argued that this approach is premature.<sup>6</sup> Issues related to the use of processing frameworks in the U.S. emerged due to inconsistent definitions of processing among classification systems<sup>7</sup> and a lack of understanding of how the public perceives processing.

This dissertation aimed to address these problems by studying the topic from different perspectives. Its primary objectives were to demonstrate the need for a common framework for classifying foods by processing level and to clarify the potential role of this framework in promoting healthful eating to child populations at risk of overweight and obesity. First, we assessed processing classification systems used in research in the U.S. by measuring agreement and comparing associations between processing level and nutrient quality among the three most commonly used in the U.S. in order to provide evidence to recommend the most rigorous one in subsequent studies. Next, focus groups were held with children and parents from low-income and diverse school districts to explore how these populations define terms related to processing, how they classify foods according to processing level, and whether they associate processing with healthfulness in comparison to how processing is described by researchers. Finally, the association

between processed food consumption, dietary quality and weight status was investigated in a sample of low-income and ethnically diverse children.

Beyond identifying the need for a common framework, these studies suggest that current systems for classifying processed foods do not necessarily align with healthfulness. Thus, the goal of translating guidance on dietary practices with respect to processed food consumption based on these systems is unrealistic. This chapter will summarize main findings of the dissertation through the lens of this overarching conclusion, discuss potential implications of these findings, and suggest avenues for future research to improve on the rigor and utility of processing frameworks in guiding healthful dietary practices.

## **Summary of methods and results**

### *Aim 1: Current food classification systems in the U.S.*

The first study was designed to critically evaluate processing classification frameworks used to assess the relationship between processed food consumption, dietary quality and health outcomes among populations in the U.S. Three systems, including the IFIC system (developed by the International Food Information Council),<sup>8</sup> Nova (developed in Brazil by researchers at the University of São Paulo)<sup>9</sup> and UNC (developed by researchers at the University of North Carolina at Chapel Hill)<sup>10</sup> frameworks were identified for comparison. Previous research using the three classification systems to explore the relationship between food processing and dietary quality led to inconsistent conclusions. Studies using the IFIC system had reported that all processing levels contributed nutrients that are typically under-consumed by Americans (including fiber, potassium, calcium, magnesium and vitamins A, C, E and D), as well as those that are over-consumed (saturated fats, added sugars and sodium).<sup>11-13</sup> Based on these findings, several studies concluded that traditional, nutrient-based recommendations were more useful for providing guidance on a healthy dietary pattern than the extent of food processing.<sup>11-13</sup> In contrast, studies using the Nova system concluded that the concentration of under-consumed nutrients in diets declined as “ultra-processed” food consumption increased, while over-consumed nutrients rose in parallel.<sup>14,15</sup> A study using the UNC system to examine household food purchases found wide variation in nutrient

content among foods from different processing levels, but noted that highly processed products were more likely to exceed the recommended limits for over-consumed nutrients.<sup>10</sup>

Other key differences between these systems were readily apparent. The IFIC system divided foods into five levels, Nova into four levels and UNC into seven levels of processing (**Table 1**). IFIC defined the lowest level of processing as “minimally processed” while Nova and UNC use the term “unprocessed and minimally processed.” Descriptors of the most processed level were varied. IFIC defined a category called “prepared foods/meals” as the highest level of processed; Nova used the term “ultra-processed” and UNC specified a category called “highly processed stand-alone.” Between 2009 and the present, Nova released multiple versions of its system, including ones that ranged from three to five processing levels, with variable definitions of categories and inconsistent example foods.<sup>16</sup>

The contradictory conclusions stemming from these studies, as well as the divergence in framework design, were striking and shed light on several key gaps, including the underlying factors driving the contradictory conclusions, and the implications for communicating messages concerning the relationship between processed foods consumption and dietary quality to consumers. Based on this evidence, we theorized that the design of the frameworks may affect conclusions of research, since foods may be categorized into different levels depending on the system used. More specifically, we hypothesized that the Nova system was more likely to classify foods as ultra or highly processed, leading this system to overestimate the impact of highly processed foods on diet quality compared to other systems, while the IFIC system would classify fewer foods as highly processed. We also hypothesized that the UNC system would allow for higher precision in coding foods due to the provision of an exhaustive list of foods categorized by processing level.<sup>10</sup> More specifically, we anticipated that the UNC system would have the highest inter-rater reliability among coders applying the system to a sample of foods. Finally, we expected that the Nova system would be a better predictor of over-consumed nutrient concentration in highly processed foods, based on consistent associations between ultra-processing and unhealthy diets in studies using Nova. To test these aims, we identified the top 100 most commonly consumed foods

among children aged 6–12 years using data from NHANES 2013-2014 and examined inter-rater reliability between two coders as well as associations between processing level and nutrient concentration between systems.

To identify the top 100 most commonly consumed foods, we compared the results of the top 100 foods consumed by weight in grams per day, count (number of times consumed) per day, and servings per day. We attempted to calculate servings consumed by merging dietary intake data from NHANES with FNDDS portion codes;<sup>17</sup> however, most foods were linked to multiple portion sizes in the FNDDS database. Thus, we cross referenced the FNDDS portions with standard portions listed in the USDA Food Composition database to determine a standard portion.<sup>18</sup> This exercise allowed us to gain an in-depth view of commonly consumed foods and compare various approaches to quantifying top dietary contributors among children. The results of this exercise are presented in **Appendix 3**. This table illustrates that quantifying the top commonly consumed foods by weight biased the list towards heavier foods like beverages and soups. Interestingly, the top 100 foods by count and servings consumed differed by 42%, but the top six foods were almost identical (white bread, whole milk, lowfat milk, American cheese and raw apples) and included a mix of highly processed and unprocessed foods. We chose the top 100 foods by serving (hereafter referred to as the top 100 most commonly consumed foods) as the most representative list of what children consume, since serving size (unlike count) controlled for the situation of a child consuming a small portion of a food several times throughout a day, or consuming a very large portion once a day.

Results demonstrate that all systems classified the majority of the top 100 most commonly consumed foods as highly processed. As hypothesized, Nova classified the most (70%) and IFIC the least (53%) as highly processed, and inter-rater reliability was highest for UNC and lowest for Nova. Although there was moderate agreement among the three systems, several food groups were consistently classified differently. These included egg dishes, meats, rice, breads, syrups and condiments (**Supplemental Figure 1**). In addition, IFIC classified significantly more foods as moderately processed, including condiments and quick breads classified as highly processed by Nova and UNC. These are products that tend to be higher in added sugars, sodium and saturated fat,

supporting our hypothesis that classification framework design is a major driver of conflicting conclusions based on these systems.

We found limited associations between processing level and under-consumed nutrients by classification systems, a result that is generally supported by studies using the IFIC system. Of the under-consumed nutrients, lower potassium was a significant predictor of moderately processed compared to minimally processed foods for the IFIC system ( $RRR = 0.97$ ,  $p = 0.01$ , 95% CI [0.94, 0.99]). This finding was likely due to IFIC's classification of tomato-based condiments (e.g. ketchup and commercially-prepared salsa) as moderately processed, as opposed to Nova and UNC which classified these products as highly processed. By classifying condiments such as ketchup (one of the top five commonly-consumed foods among children) as moderately processed, the IFIC system may also overestimate the contribution of moderately processed foods to added sugar and sodium intake compared to Nova and UNC, as supported by studies using this system.

Lower vitamin D was a significant predictor of highly compared to minimally processed foods for the UNC system ( $RRR = 0.06$ ,  $p = 0.04$ , 95% CI [0.00, 0.83]), which was due to UNC's classification of eggs and egg dishes cooked at home as minimally processed. As noted above, the classification of home-cooked foods was ambiguous in the IFIC and Nova systems and may be a source of misclassifications. UNC was also unique in classifying plain peanut butter and commercially-produced fruit-based smoothies as minimally processed. Peanut butter is high in saturated fats and potassium, while smoothies are high in under-consumed nutrients including vitamin A, potassium and fiber.<sup>18</sup> Linear discriminant plots, used to visually ability of frameworks to discriminate processing levels by nutrient concentration showed the greatest spread for the UNC system, an indication of better discrimination of processing levels by nutrient concentration.

Higher added sugar and sodium were significant predictors of highly compared to minimally processed foods for all three systems, supporting general conclusions of studies that used the UNC system.<sup>10</sup> As mentioned, all systems classified the majority of foods as highly processed. Several food groups stood out as potential drivers of the link between high processing and added sugar, including sweetened breakfast cereals, grain-

based desserts, ice-cream, candy and sugar-sweetened beverages (SSBs). Salty snacks, pizza and French fries were drivers of the link between processing and added salt.

To our knowledge, only one study has assessed agreement between processing classification systems using objective outcome measures.<sup>5</sup> This paper assessed seven systems used in varying countries, utilized a sample of food groups (instead of individual foods) for comparison, and dichotomized all processing categorizations. Despite differences in methodology, the authors reported similar results. The Nova system was found to have the lowest inter-rater reliability and agreement with other systems, while the UNC system had the highest.<sup>5</sup> The analysis was focused on descriptive aspects of processing frameworks. Thus, our assessment of the impact of framework on the association between processing level and nutrient concentration is unique. This analysis also established the utility of linear discriminant plots in combination with multinomial logistic regression to explore the relationship between processing and nutrient concentration.

#### *Aim 2: Child and parent perceptions of processed foods*

For Aim 2, we conducted focus groups with a sample of children from low-income and ethnically diverse backgrounds and, separately, with a diverse group of parents from a variety of ethnic and immigrant backgrounds. In the first section, focus group participants discussed words related to processing, including “fresh,” a term often associated with unprocessed foods, “man-made” and “machine-made,” terms often associated with highly processed foods, as well as “unprocessed” and “processed.” Both children and parents associated “fresh” with fruits and vegetables, with a few mentioning organic and unexpired foods. Interestingly, several children *and* parents interpreted the term as “just cooked.” Among parents, this interpretation was only voiced by foreign-born participants, suggesting that cultural factors may play a role in perceptions of food terms. “Man-made” elicited some associations with highly processed foods (e.g. candy, junk food), as well as the literal interpretation “made by men,” while machine-made was more consistently associated with packaged foods that are likely to be highly-processed. These terms gave participants a lexicon to employ for direct discussion of processed foods. As expected, “fresh” was used by children and parents to describe “unprocessed,”

but a handful of participants from both populations were not familiar with the term, and a few cited foods unfit for consumption, such as uncooked products and gum. Two groups of children also settled on unprocessed as machine-made junk foods, representing a definition that was reverse to that of researchers. Children and parents were more familiar with “processed,” and made associations with negative food characteristics such as unhealthfulness, factory production and convenience.

During the card sorting task, participants described how they would classify six foods by processing level. Five overarching themes emerged from child descriptions, which overlapped significantly with parent themes.

*Added ingredients* emerged as the most relevant theme for categorizing foods. Added sugar, salt and “chemicals” were brought up to describe higher degrees of processing, while having fewer added ingredients was used to describe lesser degrees of processing. This theme was well-aligned with Nova’s definition of “unprocessed/minimally processed” (i.e. foods altered in ways that do not introduce any substance)<sup>19</sup>, and processed (i.e. manufactured by adding substances like oil, sugar or salt),<sup>20</sup> as well as UNC’s criteria for distinguishing foods.<sup>10</sup> However, participants were unclear about which “chemicals” were added to processed products. Interestingly, papers authored by researchers who developed the Nova classification system implicate additives as ingredients responsible for making “ultra-processed” hyper-palatable and addictive.<sup>19,21</sup> Experts have noted that these claims are tenuous and are not backed by scientific research.<sup>16</sup>

*Packaging*, especially cans, was associated with higher degree of processing. Although the Nova framework includes several references to packaged products in their definitions of processing categories,<sup>19</sup> UNC and IFIC do not use packaging *per se* as a criteria for assessing processing level. Products such as canned produce or meats can range from “basic” processing for the purposive of preservation to highly processed depending on the presence or absence of added ingredients.<sup>8,10</sup>

*Preparation* was also a common theme in child and parent groups, emerging in discussions of factory versus home-cooked foods. The notion of industrial versus artisan or homemade products is a major theme underpinning the Nova and UNC systems.<sup>20</sup> Lesser themes brought up by children included *growing method*, such as whether or not

the product grew in a garden, and *change in state or appearance*. In the latter, children struggled to describe how an apple could be transformed from a whole fruit to a liquid, reasoning that a dramatic “change, or process” must have occurred. Parents also brought up the theme of *convenience* as integrally linked to highly processed foods.

Throughout the card sorting exercise, certain clear connections to healthfulness emerged. In particular, added ingredients, packaging, factory-production and convenience (for parents) were associated with less healthful foods. Finally, snack choices for children were discussed during parent focus groups. Healthfulness and children’s food preferences were the main criteria for choosing snacks, findings that are supported in related literature.<sup>22</sup>

The striking similarity between child and parent focus group results, despite inconsistent recognition of the terms “processed” and “unprocessed” in focus groups, suggests that the concept of processing is easily grasped when some context is provided. These focus groups were designed to give participants a lexicon of phrases to talk about processing, with the intention of enabling a discussion of the topic even in cases of unfamiliarity with the terms. To our knowledge, this approach to eliciting thoughts about processed foods is unique, and sheds light on a possible approach to communicating the topic of processing to consumers.

The overlapping themes between child and parent groups also suggest that communications aimed at these populations could be based on similar content. However, messaging strategies for parents and children require unique approaches given obvious differences in their roles as consumers. Parents serve as role-models for child eating behaviors and are shown to influence both healthful and unhealthful dietary patterns.<sup>22-25</sup> Results from our study suggest that different cultural attitudes towards processed foods may affect the types of foods that parents serve to children. Foreign-born parents cited better access to fresh fruits and vegetables in their home countries and difficulty preparing homemade foods due to time constraints. While all parents cited lack of time as a barrier to cooking at home, foreign-born parents stressed a *shift* from time for cooking from scratch in their home countries to a reliance on more ready-made products. Other evidence has demonstrated that recent immigrants consume fewer fresh fruits and vegetables due to unfamiliarity with available produce in the U.S.<sup>26</sup> Taken together, this

suggests that providing parents with support for preparing familiar dishes with available products may encourage consumption of minimally processed foods.

Child's preferences were shown to have a large influence on snack choice. There is some evidence to suggest that dietary acculturation among immigrant families can lead to purchases of highly processed foods in an effort to become more "Americanized."<sup>27,28</sup> Foreign-born parents were also less likely to understand the meaning of terms related to processing, suggesting that communication on the topic within the context of healthy eating may be beneficial. However, while children are more easily accessed through school and after-school environments, parents are often more difficult to reach. Low-income parents may be less likely to participate in nutrition education and intervention efforts due to time constraints, unstable schedules and lack of transportation.<sup>29</sup> Future work is needed to explore major sources of nutrition and dietary advice for parents, and to design communication strategies tailored to various ethnic groups that allow for flexible participation.

*Aim 3: Associations between processed food consumption, diet quality and weight status*

Our third aim tested the association between processed food intake, dietary quality (HEI-2015) and weight status (BMIz) in youth from low-income and minority backgrounds. As described in Aim 1, evidence on the association between processed food intake and dietary quality is mixed.<sup>10,12,15</sup> Associations between processed food intake and weight status are equally unclear, with limited evidence from children in the U.S.<sup>30,31</sup> For this study, we used the UNC framework to categorize foods, as this system was found to have the highest inter-rater reliability and ability to predict the nutrient concentrations of foods based on their degree of processing, as described in Aim 1. Specifically, we found that high amounts of added sugar and sodium were predictive of high processing level, a finding supported by a study of the relationship between processing level and nutrient concentration of household purchases using the UNC system.<sup>10</sup> Based on this evidence, in Aim 3, we hypothesized that greater intake of highly processed foods would be associated with lower dietary quality. We also anticipated that a more highly processed diet would be associated with higher weight status, since studies have shown associations between unhealthy dietary patterns and excess adiposity during

childhood.<sup>3,32</sup> Given conflicting evidence on the association between processing and weight status,<sup>30</sup> along with established links between poor dietary quality and excess weight in children,<sup>33</sup> we further posited that the association between processed food consumption and weight status would be mediated by dietary quality.

As expected, we found an association between highly processed food intake and lower dietary quality in our sample. Specifically, a 10% point increase in energy from HPF was associated with a 2.0 [95% CI (-2.7, -1.2)] point decrease in HEI-2015 score after controlling for maternal education and school meal program participation. Greater intake of unprocessed/minimally processed foods was associated with higher dietary quality. More specifically, a 10% increase in energy from unprocessed food was associated with a 2.9 [95% CI (2.1, 3.8)] point increase in HEI-2015 score. Children in our study had a mean HEI-2015 score of 49.9 (SD 13.4), comparable to national averages, with higher scores on weekdays compared to weekends. Highly-processed foods contributed 40% of daily energy on average and did not vary significantly between weekdays and weekends.

In Aim 1, we demonstrated that higher degree of processing was associated with higher concentration of added sugars and sodium, regardless of the processing classification system used. In Aim 3, we see that the association between processing level and nutrient concentration extends to overall diet quality. Despite some methodological issues involved with use of the Nova classification system as described in Aim 1, inverse relationships between highly or “ultra” processed food consumption and dietary quality are consistently demonstrated in the literature.<sup>30,34</sup>

Although we found positive associations between highly processed food intake and dietary quality, it is also important to note that this study does not prove that processing *per se* is associated with dietary quality. As we saw from Aim 1, many highly processed foods consumed by children are high in sodium and added sugars, including cereals and grain-based desserts like cookies and cakes. An underlying argument of the UNC and Nova systems is that processed foods are drivers of poor dietary quality and excess weight due to *processes* unique to industrial food manufacturing.<sup>21</sup> However, it is also possible that home-cooked foods contribute equally to poor dietary patterns, or that the nutrient profiles of many highly processed foods are linked to weight status. Further

work is necessary to establish whether it is the processing that is responsible for dietary shifts or other characteristics that happen to be common to industrially-produced foods.

Somewhat surprisingly, percent of calories from highly processed foods was not associated with higher BMIz score as hypothesized. Results from studies examining associations between processed food consumption and obesity are mixed,<sup>30,35,36</sup> and there is limited research in U.S. child populations. Research demonstrates that physical activity is equally important for obesity prevention in children, suggesting the this variable may be important to include as a covariate in studies examining the link between processing and weight status.<sup>37</sup> It is possible that the processing classification system used was not sensitive enough to detect a difference by weight status. The relative homogeneity of the study population may also play a role. Over one-third of youth in the sample were obese, compared to 18.5% nationally. Even more striking, there were no underweight children in the population. Without adequate weight variability, it may be difficult to detect the effect of processed food consumption on weight status. Similar issues arise with SES status and dietary patterns. Over 92% of the sample qualified for free school meals, a measure indicative of low household economic status. There are strong associations between SES status and weight status in the literature.<sup>2</sup> It is also possible that under-reporting occurred at a higher rate than normal given the high prevalence of obesity, which may further diminish variability of the sample. Together, these observations suggest that common characteristics of the sample may have prevented some associations between processing and weight status from emerging.

Several questions regarding the role of the school environment in processed food consumption emerge from this study. Specifically, the role of the school environment in encouraging or discouraging consumption of highly processed as well as unprocessed foods among U.S. school children is unknown. A study of 1,357 school children in Brazil found that children who consumed two school meals daily has 18% lower intake of energy from ultra-processed foods, and those who consumed three meals per day had 26% lower intake compared to children who ate no school meals.<sup>38</sup> In Aim 3, we were unable to assess whether school meal consumption was associated with better dietary quality due to very high school meal participation that limited sample variability. There is some evidence to suggest that bringing lunch from home is associated with very high

intake of highly processed foods among U.S. school children (Blondin et al.), as well as evidence that replacing packed lunch with school provided meals leads to increased dietary quality.<sup>39</sup> Given the observed inverse association between highly processed foods consumption and dietary quality, this suggests that interventions aimed at limiting highly processed foods in packed lunches may improve dietary quality of meals eaten at school.

The impact of structured versus unstructured time on processed food consumption is also unknown. A wide body of evidence points to excess weight gain during summer months compared to the school year, but the determinants of summer weight gain remain unclear.<sup>40</sup> Assessing daily energy intake by processing level during the school year compared to summer months could shed light on whether or not highly processed food intake is associated with accelerated summer weight trajectories. These avenues of research could also present an opportunity to test the effects of a campaign to reduce highly processed food consumption during specific meals, such as snacks or lunches brought from home, or during periods associated with heightened risk of accelerated weight gain such as summer vacation.

### **Issues related to current classification systems used in research**

A principal goal of this dissertation was to objectively compare current processing classification systems used in the U.S. in order to identify the most rigorous framework and recommend its use in future research. Along those lines, we aimed to provide evidence of the need for a common system for examining the extent of food processing and its relationship to health outcomes. Several researchers have published criticisms of the Nova and IFIC frameworks,<sup>7</sup> and one study found UNC to have the highest rate of agreement between coders, similar to our results.<sup>5</sup> Based on this evidence, and readily observable characteristics of the systems such as their stated purpose, language, ease of interpretation, and consistent presentation across studies, we hypothesized that the UNC system would perform best via two objectives measures. This hypothesis was supported by our findings. However, the aim of identifying an optimal framework for use in the U.S. remains elusive for a number of reasons.

*Theoretical and scientific underpinnings.* The purpose of the Nova framework is never stated in articles, yet the authors describe clear and proven links between “ultra-

processed” foods and poor health before presenting definitions of their framework for classifying processed foods.<sup>41</sup> This is problematic, since it suggests that the authors set out to prove a hypothesis concerning the negative relationship between certain processed foods and healthfulness. To illustrate this point, a 2009 editorial published by Monteiro, the leading author of the Nova system, states that, “Diets that include a lot of ultra-processed foods are intrinsically nutritionally unbalanced and intrinsically harmful to health.”<sup>41</sup> At the time of that article’s publication, there was no evidence to support the claim that diets high in “ultra-processed” foods were intrinsically harmful to health, particularly because the term ultra-processed had yet to be defined. Ingredients such as emulsifiers are cited as an indication of ultra-processing by Monteiro and colleagues.<sup>20</sup> However, emulsifiers are classified as Generally Recognized as Safe for consumption by the Food and Drug Administration.<sup>42</sup> In addition, the process and rationale behind development of the framework are never explained, so it is unclear how the authors established the terms and definitions. The UNC system is based off the Nova system, but was expanded to capture the complexity of the food supply in the U.S.<sup>10</sup> Therefore, it shares a similar lack of scientific rigor in terms of its development.

The IFIC system, as described in the Understanding Our Food Communications Toolkit, was developed to describe the continuum of processed foods available to consumers.<sup>8</sup> The toolkit stresses positive aspects of processing, such as the provision of under-consumed nutrients through fortification, enhanced food safety and enhanced convenience. As with the Nova system, no explanation of the procedure for establishing processing terms or definitions is offered. One article mentions the use of focus groups to develop terms used to describe processing level, but more specific results of this qualitative research are not published.<sup>13</sup> An additional concern is that IFIC is supported by at least twenty-four companies from the food, beverage and agricultural industries, including The Coca-Cola Company, General Mills and McDonald’s, all producers of processed foods that have been associated with poor diet.<sup>43</sup> Analyses utilizing the IFIC system to examine the relationship between processing and diet quality have concluded that healthful and unhealthful foods exist among all processing levels.<sup>11</sup> This contrasts with our findings from Aim 3 using the UNC system, and indicates a potential source of bias in the development of the IFIC system.

*Precision.* In Aim 1, we demonstrated that the Nova and IFIC frameworks were not sufficiently precise to identify mutually exclusive food groupings, as evidenced by low inter-rater reliability when applied to a sample of 100 foods. The fact that two nutrition researchers with PhD and RD credentials in nutrition did not reach a high consensus when classifying foods is problematic, indicating that these systems lack the precision to be consistently applied to a variety of food databases. Moreover, the 100 foods used in our analysis were chosen to be a representative sample of the foods most commonly consumed by children in the U.S., and therefore did not contain atypical foods.

*Utility in improving dietary patterns.* In contrast, the UNC system provides an exhaustive list of foods sold in U.S. supermarkets matched to their intended categorization among seven levels of processing.<sup>10</sup> This approach allowed for very high inter-rater reliability in our Aim 1 study as well as in a review of classification systems.<sup>5</sup> However, the need for such a detailed codebook indicates that the system is not readily accessible to consumers. Nova, and UNC as an extension of the Nova system, were developed with the intention of drastically reducing consumption of foods from the highest processing levels.<sup>41</sup> However, it is unclear whether consumers could effectively apply the definitions to specific foods. The UNC system has the most levels, and thus is the most complex coding scheme. To our knowledge, no effort has been made to communicate key elements of the system to consumers in the U.S. In Aim 2, we described how a sample of low-income children and parents conceptualized processing, demonstrating that this study population had a working knowledge of the topic that could be leveraged to talk about healthful eating. Participants also had preconceived notions of the link between processing and unhealthful qualities. However, whether these beliefs impacted consumption of processed foods was not explored. A key finding was that parents often favored children's taste preferences above healthfulness when choosing snacks, suggesting that additional information regarding the effects of processing on nutrient quality are unlikely to change behavior. A better communication approach might be that of IFIC, which stresses making healthy food choices within processing categories. Particularly in the case of low-income consumers, communicating the benefits of certain processing methods, such as freezing for long-term fruit and vegetable storage, may be a

more salient messaging approach. Future studies should assess whether there is enough variability within categories to support this method.

*Unintended consequences.* The IFIC framework acknowledges that certain processes employed at an industrial scale can be potentially harmful to health, while others have a direct and positive impact on nutritional quality.<sup>8</sup> Fortification of enriched wheat flour is a classic example of the benefits of industrial food processing and is particularly relevant for individuals with lower overall dietary quality. In other cases, less processed versions are undoubtedly more healthful. Regular consumption of processed and cured meats containing nitrites are implicated in the development of colon cancer. Because of the associated disease risk, the Dietary Guidelines for Americans (DGA) advises individuals to limit consumption of processed meat products.<sup>44</sup> Diets high in whole grain breads are shown to be more healthful than those characterized by refined grain breads,<sup>45</sup> and low sodium versions of canned foods, which are also less processed, may have benefits for individuals at risk of high blood pressure.<sup>46</sup> While plain milk is lower in sugar than flavored milks, experts have debated whether encouraging children to drink flavored milk is a better choice to prevent calcium deficiencies, as flavored milk is better than no milk at all.<sup>47</sup> A variety of factors may contribute to decisions regarding processed food consumption, such that the optimal level of processing depends on both inter- and intrapersonal elements as well as the particular food group in question.

In developing guidance related to food processing, it is important to consider potential unintended consequences. Low-income families may choose to purchase highly processed foods for a variety of reasons, including the need for shelf-stable products, lack of time, skills or resources to prepare meals from scratch, or perceived or actual lower cost as compared to less processed items. Although there is evidence to suggest that nutritious and less nutritious foods in supermarkets have similar costs,<sup>48</sup> the relative cost of minimally compared to highly processed foods has not been assessed and warrants further investigation. Children's preferences also play a role. In Aim 2, we found that parents are motivated to serve healthy snacks to their children, but they are also risk averse; that is, they prefer to serve a food that they know their child likes rather than risk wasting a more healthful item. Indeed, in a study of snack choices, children were presented with a buffet of apple-based snacks ranging from minimally to ultra-

processed.<sup>49</sup> Children selected and consumed more ultra-processed compared to minimally processed foods and reported preferring the taste of the most processed items. Moreover, a qualitative study of ultra-processed food consumption among SNAP participants revealed that ultra-processed products were generally preferred or requested by children, and these products were often used as a tool to protect against food insecurity at the end of the monthly benefit cycle.<sup>50</sup> Future research examining the intersection between the economics of processed versus unprocessed food consumption and dietary guidance is needed.

### **Implications for policy and communication**

Along with a steep rise in research devoted to food processing, media attention to the topic has increased significantly over the past decade. A 2017 survey by the American Heart Association found that almost 50% of consumers report trying to consume fewer processed foods.<sup>51</sup> However, a survey from the same year by the IFIC found that consumers were concerned about processing, but confounded characteristics such as “organic,” “natural,” and “low sugar” with definitions of less processed foods.<sup>52</sup> Almost 80% reported encountering conflicting information about what to eat or avoid, with many doubting their food choices based on conflicting advice. We found similar reports of concern related to eating and serving processed foods among parents interviewed in Aim 2. Further, we found that parents reported that balancing children’s preferences while prioritizing health was a challenge. Taken together, this suggests that consumers are faced with both conflicting advice around processed foods and healthful eating, and competing priorities at home.

The topic of processing has been embraced by public health authorities in Brazil as a practical way to promote healthier preparation methods (cooking from scratch instead of ready-to-heat meals), greater consumption of minimally processed foods (fruits vegetables, meats and milk), and reduced consumption of “ultra-processed” convenience products (snacks, soft drinks and pre-packaged items).<sup>6</sup> The Dietary Guidelines for the Brazilian Population incorporated this guidance in its 2014 report.<sup>6</sup> There is limited evidence that knowledge and understanding of the processing guidelines may reduce

highly processed food consumption and increase fruit and vegetable intake, but more research is necessary.<sup>53</sup>

In the U.S., there has been little official guidance concerning processing, with the exception of advice to avoid processed meat in the 2015-2020 DGA.<sup>44</sup> Despite strong associations between intake of certain cooked red and processed meats and incidence of cancer, both red and processed meat intake are on the rise in the U.S.<sup>54</sup> Meat labeling regulations may be a source of confusion for consumers. The USDA has several conflicting regulations around front-of-package meat labels, with loose guidelines concerning products that can be labeled “natural,” including meats that contain celery-derived forms of nitrites (the compounds implicated in cancer development).<sup>55</sup> Similar contradictory messaging is found on many highly processed products with claims such as “fresh,” “non-GMO,” “all natural” and “simple ingredients.” The IFIC survey reported increasing concerns about carcinogenic compounds among Americans, along with high value associated with “natural” products.<sup>52</sup> We found from Aim 2 that parents and children associated many of these claims with less processing and, more importantly, healthfulness. However, organic or non-GMO ingredients are certainly no guarantee of “healthy” products. Stricter regulations regarding the use of these claims may help to ameliorate consumer confusion, and greater transparency is necessary. More work in developing rigorous definitions of processing level could also pave the way for more transparent regulations concerning labeling of products with respect to degree of processing.

### **Directions for future research**

The factors that influence dietary patterns and their associated impacts on health are multifaceted, necessitating a similarly multidimensional approach to improving diet among low-income children. As discussed, current processing classification frameworks fail to acknowledge the complex interactions between individuals, communities, environments and wide-reaching policies that determine how and what children eat. For processing frameworks to be truly functional and useful to both researchers and consumers, each of these strata must be considered. Social-ecological models, which posit that all layers of influence (ranging from individual to policy factors) are important

in determining behaviors, and can be useful for organizing and identifying targets for improving child eating habits. The model can also help identify stakeholders to involve in the development of a useful framework for classifying processed foods.

**Figure 3** presents examples of key players to consider in thinking about the design of processing frameworks. At the individual level, cognitive factors such as perceptions and understanding of food processing, eating behaviors and food preferences, and individual biology should be considered. The household and community food environment, as well as knowledge, cultural beliefs and behaviors relating to processed food among family and broader social circles can be examined at the community level. Issues of methodology, approaches and biases of researchers studying the effects of processed food consumption may be factored in at the research level. And finally, the past and future influence of policy makers and processed food manufacturers should be carefully considered.

Some of these layers of influence were examined in this dissertation, some have been explored in related literature, while others remain to be investigated. Future efforts around development of processing frameworks would benefit from input gathered across multiple sectors. This could be achieved with an advisory committee comprising experts from relevant nutrition and public health fields (nutrition and food scientists, health communicators, behavioral theorists) as well as policy makers and food industry representatives. Developing a framework based on input from multiple perspectives may also help to influence communication efforts and policies related to marketing and consumption of processed foods.

### **Suggestions for expansion on the present work**

The research included in this dissertation provides several opportunities for further exploration and study. In Aim 1, our use of the 100 most commonly consumed foods among youth participating in NHANES does not fully reflect the breadth of foods and processing levels consumed by child populations. As a proof of concept, this aim demonstrated the feasibility of our analysis approach, and can be applied to a larger sample of foods. During Aim 2, we were unable to recruit child-parent dyads, and thus were did not examine the bidirectional relationship between child and parent perceptions.

Future studies examining understanding and communication of processed foods could evaluate the effect of parent attitudes and beliefs on child understanding and consumption of processed foods. Finally, the use of cross-sectional data for Aim 3 allowed for conclusions regarding associations between relationships of interest, but not causality. Prospective or longitudinal cohort studies in similar populations could examine the impact of changes in the proportion of energy over time on dietary quality, weight status and other health outcomes.

## **Conclusion**

Although processed foods have existed in the human diet for over 2 million years, their role in terms of nutrition and health only recently entered the spotlight. Over the past decade, research and public interest on the topic of processing and health has grown exponentially. Much of the current attention has focused on processing in the context of poor dietary quality, high obesity rates, and widening health disparities among both adults and children in the U.S. However, the lack of standard definitions of processing level has led to contradictory findings in research. Moreover, consumer audiences are unlikely to be receiving clear guidance on processed food consumption given inconsistent definitions used in research. The overarching aim of this dissertation was to demonstrate the need for a common framework for classifying foods by processing level, and to clarify the potential role of this framework in promoting healthful eating to child populations at risk of overweight and obesity.

Taken together, the findings of this work highlight key methodological challenges in studying associations between processing, dietary quality and weight status. Current frameworks for classifying foods are discrepant, and lack adequate foundations in theory, scientific rigor, precision and utility. Through a novel analytical approach, we demonstrated that the UNC system is the most reliable framework available in the U.S. At the same time, we show that processing classification systems are not sensitive enough to distinguish among processing levels using measures of nutrient quality. However, these systems may be appropriate for identifying highly processed foods characterized by added sugars and high salt content. In considering recommendations for children's diets, establishment of a nationally recognized system for the U.S. food system should consider

the utility of processing classification to predict dietary quality and may function best when interpreted as one aspect of diet within the context of traditional food and nutrient classifications.

Our qualitative research sheds light on an unexplored topic among low-income children and parents in the U.S. Both populations have a working knowledge of processing that could be leveraged to encourage healthier eating patterns; however, their understanding was not always consistent with the classification systems used in research. These studies lend support to our conclusions from Aim 1, namely that the vocabulary used to talk about processing used by researchers and consumers must be reconciled to translate findings into actionable messages. To that end, multi-stakeholder approaches are needed to develop a common language that is accepted by the research and food manufacturing communities and is comprehensible to consumers. In addition, more research is needed to develop educational approaches to teach the concept of processing to a variety of consumer audiences.

Finally, we demonstrated that among a sample of low-income and ethnically diverse children, highly processed food consumption was associated with poorer diet quality, but not obesity. This study confirmed the finding that the majority of energy consumed by low-income children is derived from highly processed foods. Together, this evidence offers insight into complementary approaches for improving dietary quality in child populations, through reducing highly processed food availability and consumption in tandem with encouraging consumption of unprocessed and minimally processed foods. Our work also sheds light on important gaps in knowledge in the relationship between processing and weight status. There is a need for more mechanistic studies to explore potential links between the components of processed foods that may be responsible for weight gain seen in other studies,<sup>56</sup> and well as longitudinal designs to assess changes in weight status over time.

We conclude with a recommendation for establishing a common framework for classifying processed foods based on optimized processing level within food categories, and developed with input across multiple sectors and stakeholder groups. Highly processed foods are, and will likely remain, a significant portion of the diets of children in the U.S. Shifting eating behavior is a complex task, requiring novel approaches and

cross-sector cooperation. Despite clear challenges to researching and communicating characteristics of processed foods, this dissertation highlights the potential of food processing to be a valuable topic for research and communication that may ultimately improve the way we approach dietary assessment and guidance.



**Figure 3.** Social-ecological framework for organizing factors to consider in designing food processing classification systems.

## REFERENCES

1. Ogden CL, Carroll MD, Fakhouri TH, et al. Prevalence of Obesity Among Youths by Household Income and Education Level of Head of Household — United States 2011–2014. *MMWR Morb Mortal Wkly Rep* 2018;67:186–189.
2. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005–2008. *NCHS Data Brief, US Department of Health and Human Services Centers for Disease Control and Prevention*. 2010;51.
3. Ambrosini GL, Emmett PM, Northstone K, Howe LD, Tilling K, Jebb SA. Identification of a dietary pattern prospectively associated with increased adiposity during childhood and adolescence. *Int J Obes (Lond)*. 2012;36(10):1299–1305.
4. Goldberg JP, Sliwa SA. Communicating actionable nutrition messages: challenges and opportunities. *Proc Nutr Soc*. 2011;70(1):26–37.
5. Crino M, Barakat T, Trevena H, Neal B. Systematic Review and Comparison of Classification Frameworks Describing the Degree of Food Processing. *Nutrition and Food Technology: Open Access*. 2017;3(1).
6. Brazil MoHo. Dietary Guidelines for the Brazilian Population, 2nd edition. In: Care SoH, ed2014.
7. Gibney MJ, Forde CG, Mullally D, Gibney ER. Ultra-processed foods in human health: a critical appraisal. *Am J Clin Nutr*. 2017;106:717–724.
8. *Understanding our food communications tool kit*. Washington, DC: International Food Information Council;2010.
9. Monteiro C, Levy R, Claro R, Ribeiro de Castro IR, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública*. 2010;26(11):2039–2049.
10. Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr*. 2015;101(6):1251–1262.
11. Eicher-Miller HA, Fulgoni VL, Keast DR. Contributions of processed foods to dietary intake in the US from 2003–2008: a report of the Food and Nutrition Science Solutions Joint Task Force of the Academy of Nutrition and Dietetics, American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. *J Nutr*. 2012;142(11):2065S–2072S.
12. Eicher-Miller HA, Fulgoni VL, Keast DR. Processed Food Contributions to Energy and Nutrient Intake Differ among US Children by Race/Ethnicity. *Nutrients*. 2015;7(12):10076–10088.
13. Weaver CM, Dwyer J, Fulgoni VL, et al. Processed foods: contributions to nutrition. *The American Journal of Clinical Nutrition*. 2014;99(6):1525–1542.
14. Steele ME, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2016;6(3):e009892.
15. Martinez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence

- from a nationally representative cross-sectional study. *Popul Health Metr.* 2017;15(1):6.
16. Gibney M. Ultra-Processed Foods: Definitions and Policy Issues. *Current Developments in Nutrition.* 2019;3(2).
  17. U.S. Department of Agriculture, Agricultural Research Service. 2018. USDA Food and Nutrient Database for Dietary Studies 2013-2014. Accessed.
  18. USDA National Nutrient Database for Standard Reference, Release 28. /nea/bhnrc/ndl. Updated Revised May 2016. Accessed December, 2017.
  19. Monteiro C, Levy R, Claro R, Ribeiro de Castro I, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saúde Pública.* 2010;26(11).
  20. Moubarac JC, Parra DC, Cannon G, Monteiro CA. Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. *Curr Obes Rep.* 2014;3(2):256-272.
  21. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr.* 2019;22(5):936-941.
  22. Horning ML, Fulkerson JA, Friend SE, Story M. Reasons Parents Buy Prepackaged, Processed Meals: It Is More Complicated Than "I Don't Have Time". *J Nutr Educ Behav.* 2017;49(1):60-66 e61.
  23. Adamo KB, Brett KE. Parental perceptions and childhood dietary quality. *Matern Child Health J.* 2014;18(4):978-995.
  24. Benton D. Role of parents in the determination of the food preferences of children and the development of obesity. *Int J Obes Relat Metab Disord.* 2004;28(7):858-869.
  25. Borah-Giddens J, Falciglia G. A Meta-Analysis of the Relationship in Food Preferences between Parents and Children. *J Nutr Educ.* 1993;25(3):102-107.
  26. Popovic-Lipovac A, Strasser B. A review on changes in food habits among immigrant women and implications for health. *J Immigr Minor Health.* 17(2):582-590.
  27. Ayala GX, Baquero B, Klinger S. A systematic review of the relationship between acculturation and diet among Latinos in the United States: implications for future research. *J Am Diet Assoc.* 2008;108(8):1330-1344.
  28. Van Hook J, Quiros S, Frisco ML, Fikru E. It is Hard to Swim Upstream: Dietary Acculturation Among Mexican-Origin Children. *Popul Res Policy Rev.* 2016;35(2):177-196.
  29. Winslow E, Bonds D, S W. Predictors of enrollment and retention in a preventive parenting intervention for divorced families. *J Prim Prev.* 2009;30:151-172.
  30. Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *Int J Behav Nutr Phys Act.* 2015;12:160.
  31. Cunha DB, da Costa THM, da Veiga GV, Pereira RA, Sichieri R. Ultra-processed food consumption and adiposity trajectories in a Brazilian cohort of adolescents: ELANA study. *Nutr Diabetes.* 2018;8(1):28.

32. Alexy U, Libuda L, Mersmann S, Kersting M. Convenience foods in children's diet and association with dietary quality and body weight status. *Eur J Clin Nutr.* 2011;65(2):160-166.
33. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? *Am J Clin Nutr.* 2014;99(1):162-171.
34. Louzada M, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr.* 2017;1-9.
35. Juul F, Martinez-Steele E, Parekh N, Monteiro CA, Chang VW. Ultra-processed food consumption and excess weight among US adults. *Br J Nutr.* 2018;120(1):90-100.
36. Mendonca RD, Pimenta AM, Gea A, et al. Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr.* 2016;104(5):1433-1440.
37. Sallis JF, Glanz K. Physical Activity and Food Environments: Solutions to the obesity epidemic. *The Milbank Quarterly.* 2009;87(1):123-154.
38. Bento BMA, Moreira ADC, Carmo ASD, Santos LCD, Horta PM. A higher number of school meals is associated with a less-processed diet. *J Pediatr (Rio J).* 2017.
39. Sabinsky MS, Toft U, Sommer HM, Tetens I. Effect of implementing school meals compared with packed lunches on quality of dietary intake among children aged 7-13 years. *J Nutr Sci.* 2019;8:e3.
40. Tanskey LA, Goldberg J, Chui K, Must A, Satchek J. The State of the Summer: a Review of Child Summer Weight Gain and Efforts to Prevent It. *Curr Obes Rep.* 2018;7(2):112-121.
41. Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutr.* 2009;12(5):729-731.
42. Shah R, Kolanos R, DiNovi M, Mattia A, KJ K. Dietary exposures for the safety assessment of seven emulsifiers commonly added to foods in the United States and implications for safety. *Food Addit Contam Part A.* 34(6):905-917.
43. International Food Information Council. <https://foodinsight.org/partners-and-supporters/>. Accessed April, 2009.
44. 2015–2020 Dietary Guidelines for Americans. 8th Edition. Available at <http://health.gov/dietaryguidelines/2015/guidelines/>. U.S. Department of Health and Human Services and U.S. Department of Agriculture;December 2015.
45. O'Neil CE, Zhanovec M, Cho SS, Nicklas TA. Whole grain and fiber consumption are associated with lower body weight measures in US adults: National Health and Nutrition Examination Survey 1999-2004. *Nutr Res.* 2010;30(12):815-822.
46. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA. Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Pediatrics.* 2013;131(1):14-21.
47. Fayet-Moore F. Effect of flavored milk vs plain milk on total milk intake and nutrient provision in children *Nutrition Reviews.* 2015;74(1).

48. Katz DL, Doughty K, Njike V, et al. A cost comparison of more and less nutritious food choices in US supermarkets. *Public Health Nutr.* 2011;14(9):1693-1699.
49. Svisco E, Byker Shanks C, Ahmed S, Bark K. Variation of Adolescent Snack Food Choices and Preferences along a Continuum of Processing Levels: The Case of Apples. *Foods.* 2019;8(2).
50. Moran AJ, Khandpur N, Polacsek M, Rimm EB. What factors influence ultra-processed food purchases and consumption in households with children? A comparison between participants and non-participants in the Supplemental Nutrition Assistance Program (SNAP). *Appetite.* 2019;134:1-8.
51. Can Processed Food be Healthy? The American Heart Association. heart.org/sodium. Published 2017. Accessed November, 2018.
52. 2012 Food and Health Survey: consumer attitudes toward food safety, nutrition and health. Washington, D.C.2012.
53. Fonseca LG, Bertolin MNT, Gubert MB, da Silva EF. Effects of a nutritional intervention using pictorial representations for promoting knowledge and practices of healthy eating among Brazilian adolescents. *PloS one.* 2019;14(3):e0213277.
54. Daniel C, Cross A, Koebnick C, Sinha R. Trends in meat consumption in the United States. *Public Health Nutr.* 2011;14(4):575-583.
55. United States Department of Agriculture, Food and Nutrition Service. <https://www.fns.usda.gov/sfsp/summer-food-service-program>. Accessed July, 2017.
56. Hall K, Ayuketah A, Bernstein S, et al. Ultra-processed diets cause excess calorie intake and weight gain: A one-month inpatient randomized controlled trial of ad libitum food intake. *Under Review.* 2019.

## **APPENDICES**

### **Appendix A: Aim 1 Supplementary materials**

*A.1: The top 100 foods categorized by processing level using three processing frameworks*

| Food with common processing level, as classified by the IFIC, Nova and UNC systems |                                  |                               | IFIC classifications, unique                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Nova classifications, unique                                                                                                                                                                                                                                   | UNC classifications, unique                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------------------------------------------|----------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Unprocessed/<br>minimally processed                                                | Milk, reduced fat (2%)           | Orange, raw                   | Tea, iced, bottled, black                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Rice, white, cooked, fat added in cooking, made with oil<br>Rice, white, cooked, fat not added in cooking<br>Butter, stick, salted<br>Maple and corn and/or cane pancake syrup blends*<br>Pancake syrup, NFS                                                   | Tea, iced, bottled, black<br>Rice, white, cooked, fat added in cooking, made with oil<br>Rice, white, cooked, fat not added in cooking<br><br>Fruit flavored smoothie drink, frozen (no dairy)<br>Egg, whole, fried with oil<br>Peanut butter<br>Egg omelet or scrambled egg, made with oil                                                                                                                                                          |
|                                                                                    | Milk, whole                      | Milk, fat free (skim)         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Moderately processed                                                               | Apple, raw                       | Fruit juice blend,            | Egg omelet or scrambled egg, made with oil<br>Egg, whole, fried with oil<br>Bread, wheat or cracked wheat<br>Tortilla, corn<br><br>Chocolate milk, ready to drink, reduced fat (2%)<br>Strawberry milk, NFS<br>Chocolate milk, ready to drink, low fat (1%)<br>Chocolate milk, ready to drink, whole<br>Butter, stick, salted<br>Italian dressing, made with vinegar and oil<br>Rice, white, cooked, fat not added in cooking<br>Rice, white, cooked, fat added in cooking, made with oil<br>Bread, white<br>Tomato catsup<br>Creamy dressing<br>Pancakes, plain<br>Waffle, plain<br>Salsa, red, commercially-prepared<br>Roll, white, hamburger bun<br>Mustard<br>Mayonnaise, regular<br>Maple and corn and/or cane pancake syrup blends<br>Roll, white, soft<br>Macaroni or noodles with cheese, made from packaged mix<br>Pancake syrup, NFS<br>Barbecue sauce | Egg omelet or scrambled egg, made with oil<br>Egg, whole, fried with oil<br><br>Pork bacon, NS as to fresh, smoked or cured, cooked<br><br><br>Italian dressing, made with vinegar and oil<br>Fruit flavored smoothie drink, frozen (no dairy)<br>Pork sausage | Bread, wheat or cracked wheat<br>Tortilla, corn<br>Pork bacon, NS as to fresh, smoked or cured, cooked<br>Chocolate milk, ready to drink, reduced fat (2%)<br>Strawberry milk, NFS<br>Chocolate milk, ready to drink, low fat (1%)<br>Chocolate milk, ready to drink, whole<br>Butter, stick, salted<br><br><br>Ham, sliced, prepackaged or deli, luncheon meat<br>Yogurt, fruit, low fat milk<br>Tea, iced, brewed, black, pre-sweetened with sugar |
|                                                                                    | Milk, low fat (1%)               | 100% juice                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    | Banana, raw                      | Grapes, raw, NS as to type    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    | Apple juice, 100%                | Watermelon, raw               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    | Lettuce, raw                     | Ground beef or patty, cooked* |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    | Orange juice, 100%               | Strawberries, raw             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    | Sugar, white, granulated or lump | Carrots, raw                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                    |                                  |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |



*A.2: Comparison between top 100 foods according to count, weight, and servings consumed per day*

Top 100 foods by count (number of times eaten), weight (grams) and servings reported by children 6–12 in NHANES 2013-2014. Differences between count and weight are highlighted in pink, differences between count and servings are in blue.

| Count                                                                   | Weight                                                                  | Servings                                                   |
|-------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------|
| Milk, reduced fat (2%)                                                  | Milk, reduced fat (2%)                                                  | Milk, reduced fat (2%)                                     |
| Milk, whole                                                             | Milk, whole                                                             | Bread, white                                               |
| Apple, raw                                                              | Milk, low fat (1%)                                                      | Tomato catsup                                              |
| Cheese, American                                                        | Gatorade G sports drink                                                 | Cheese, American                                           |
| Milk, low fat (1%)                                                      | Apple, raw                                                              | Milk, whole                                                |
| Bread, white                                                            | Orange juice, 100%, canned, bottled or in a carton                      | Apple, raw                                                 |
| Lettuce, raw                                                            | Soft drink, pepper type                                                 | Milk, low fat (1%)                                         |
| White potato, french fries, from frozen, deep fried, from home or store | Tea, iced, brewed, black, pre-sweetened with sugar                      | Bread, wheat or cracked wheat                              |
| Grapes, raw, NS as to type                                              | Milk, fat free (skim)                                                   | Creamy dressing                                            |
| Salty snacks, corn or cornmeal base, tortilla chips                     | Fruit flavored smoothie drink, frozen (no dairy)                        | Peanut butter                                              |
| Orange juice, 100%, canned, bottled or in a carton                      | Tea, iced, bottled, black                                               | Ice cream, regular, flavors other than chocolate           |
| Peanut butter                                                           | Macaroni or noodles with cheese, made from packaged mix                 | Cheese, Cheddar                                            |
| Tomatoes, raw                                                           | Ice cream, regular, flavors other than chocolate                        | Banana, raw                                                |
| Rice, white, cooked, fat not added in cooking                           | Lemonade, fruit flavored drink                                          | Salty snacks, corn or cornmeal base, tortilla chips        |
| Ice cream, regular, flavors other than chocolate                        | Chocolate milk, ready to drink, reduced fat (2%)                        | Soft drink, fruit flavored, caffeine free                  |
| Mayonnaise, regular                                                     | Chocolate milk, ready to drink, reduced sugar, NS as to milk            | Cookie, chocolate chip                                     |
| Roll, white, hamburger bun                                              | Chocolate milk, NFS                                                     | Ham, sliced, prepackaged or deli, luncheon meat            |
| Jelly, all flavors                                                      | White potato, french fries, from frozen, deep fried, from home or store | Pancakes, plain                                            |
| Strawberries, raw                                                       | Rice, white, cooked, fat not added in cooking                           | Chicken or turkey loaf, prepackaged or deli, luncheon meat |
| Milk, fat free (skim)                                                   | Chocolate milk, ready to drink, low fat (1%)                            | White potato chips, regular cut                            |
| Cookie, chocolate chip                                                  | Milk, NFS                                                               | Apple juice, 100%                                          |
| Cheese, Cheddar                                                         | Grapes, raw, NS as to type                                              | Gatorade G sports drink                                    |

|                                                                                                      |                                                                                                |                                                                                          |
|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Cracker, snack                                                                                       | Chocolate milk, ready to drink, whole                                                          | Pizza with pepperoni, from restaurant or fast food, regular crust                        |
| Macaroni or noodles with cheese, made from packaged mix                                              | Bread, white                                                                                   | Fruit flavored drink, powdered, reconstituted                                            |
| Gatorade G sports drink                                                                              | Rice, cooked, NFS                                                                              | Tortilla, corn                                                                           |
| Pancakes, plain                                                                                      | Chicken nuggets, from fast food / restaurant                                                   | Soft drink, cola                                                                         |
| Chocolate milk, ready to drink, reduced fat (2%)                                                     | Strawberries, raw                                                                              | Cheese, Mozzarella, part skim                                                            |
| Ham, sliced, prepackaged or deli, luncheon meat                                                      | Soft drink, cola, diet                                                                         | Lettuce, raw                                                                             |
| Chicken or turkey loaf, prepackaged or deli, luncheon meat                                           | Yogurt, fruit, low fat milk                                                                    | Salty snacks, corn or cornmeal base, corn puffs and twists; corn-cheese puffs and twists |
| Yogurt, fruit, low fat milk                                                                          | Cookie, chocolate chip                                                                         | Capri Sun, fruit juice drink                                                             |
| Chicken nuggets, from fast food / restaurant                                                         | Pancakes, plain                                                                                | Orange juice, 100%, canned, bottled or in a carton                                       |
| Cheese, Mozzarella, part skim                                                                        | Salty snacks, corn or cornmeal base, tortilla chips                                            | Chicken nuggets, from fast food / restaurant                                             |
| Ice pop                                                                                              | Tea, iced, instant, black, pre-sweetened with sugar                                            | Sugar, white, granulated or lump                                                         |
| Tortilla, corn                                                                                       | Gatorade G2 sports drink, low calorie                                                          | Soup, mostly noodles                                                                     |
| Rice, cooked, NFS                                                                                    | Tomatoes, raw                                                                                  | Orange, raw                                                                              |
| Ground beef or patty, cooked, NS as to percent lean (formerly NS as to regular, lean, or extra lean) | Cheese, American                                                                               | Waffle, plain                                                                            |
| Chocolate milk, ready to drink, low fat (1%)                                                         | Fruit smoothie, with whole fruit and dairy                                                     | Salsa, red, commercially-prepared                                                        |
| Butter, stick, salted                                                                                | Roll, white, hamburger bun                                                                     | Fruit leather and fruit snacks candy                                                     |
| Popcorn, popped in oil, buttered                                                                     | Chicken or turkey vegetable soup with rice, Mexican style, home recipe (Sopa / Caldo de Pollo) | Jelly, all flavors                                                                       |
| Tea, iced, brewed, black, pre-sweetened with sugar                                                   | Waffle, plain                                                                                  | Rice, white, cooked, fat not added in cooking                                            |
| Froot Loops                                                                                          | Pizza, cheese, from school lunch, thick crust                                                  | Milk, fat free (skim)                                                                    |
| Chocolate milk, NFS                                                                                  | Cheeseburger with tomato and/or catsup, on bun                                                 | Fruit juice blend, 100% juice                                                            |
| Pork bacon, NS as to fresh, smoked or cured, cooked                                                  | Burrito with meat                                                                              | Cracker, snack                                                                           |
| Waffle, plain                                                                                        | Soft drink, fruit flavored, diet, caffeine free                                                | Pizza, cheese, from restaurant or fast food, regular crust                               |
| Corn, yellow, cooked, from frozen, fat not added in cooking                                          | Ice pop                                                                                        | Roll, white, hamburger bun                                                               |
| Breakfast tart                                                                                       | Corn, yellow, cooked, from frozen, fat not added in cooking                                    | Pork bacon, NS as to fresh, smoked or cured, cooked                                      |

|                                                                    |                                                                                                      |                                                                                                                   |
|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Cucumber, raw                                                      | Macaroni or noodles with cheese and meat, prepared from Hamburger Helper mix                         | White potato, french fries, from fast food / restaurant                                                           |
| Chocolate milk, ready to drink, reduced sugar, NS as to milk       | Ground beef or patty, cooked, NS as to percent lean (formerly NS as to regular, lean, or extra lean) | Mustard                                                                                                           |
| Honey Nut Cheerios                                                 | Soy milk                                                                                             | Grapes, raw, NS as to type                                                                                        |
| Cheese, NFS                                                        | Tortilla, corn                                                                                       | Chocolate milk, ready to drink, reduced fat (2%)                                                                  |
| Roll, white, soft                                                  | Pizza with meat, prepared from frozen, thin crust                                                    | Ice pop                                                                                                           |
| Frosted Flakes, Kellogg's                                          | Pizza, cheese, from restaurant or fast food, thin crust                                              | Strawberry milk, NFS                                                                                              |
| Lemonade, fruit flavored drink                                     | Grape juice, 100%                                                                                    | Breakfast tart                                                                                                    |
| Soft drink, pepper type                                            | Chicken patty, fillet, or tenders, breaded, cooked                                                   | Watermelon, raw                                                                                                   |
| Pizza, cheese, from school lunch, thick crust                      | Lasagna with meat, frozen                                                                            | Pretzels, hard                                                                                                    |
| Tea, iced, bottled, black                                          | Pizza with pepperoni, from restaurant or fast food, thick crust                                      | Ground beef or patty, cooked, NS as to percent lean (formerly NS as to regular, lean, or extra lean)              |
| Milk, NFS                                                          | Lettuce, raw                                                                                         | Soft taco with meat                                                                                               |
| Taffy                                                              | Corn dog (frankfurter or hot dog with cornbread coating)                                             | Egg omelet or scrambled egg, made with oil                                                                        |
| Chocolate milk, ready to drink, whole                              | Chicken patty, fillet, or tenders, breaded, cooked, from fast food / restaurant                      | Spaghetti with tomato sauce and meatballs or spaghetti with meat sauce or spaghetti with meat sauce and meatballs |
| Chicken nuggets                                                    | Chicken or turkey loaf, prepackaged or deli, luncheon meat                                           | Froot Loops                                                                                                       |
| Cheerios                                                           | Ham, sliced, prepackaged or deli, luncheon meat                                                      | Tea, iced, brewed, black, pre-sweetened with sugar                                                                |
| Cinnamon Toast Crunch                                              | Milk shake, fast food, flavors other than chocolate                                                  | Quesadilla, just cheese, meatless                                                                                 |
| Lucky Charms                                                       | Burrito with beans, meatless                                                                         | Mayonnaise, regular                                                                                               |
| Egg omelet or scrambled egg, made with oil                         | Ice cream, regular, chocolate                                                                        | Cookie, butter or sugar                                                                                           |
| Cheese, cream                                                      | Chocolate milk, ready to drink, fat free (skim)                                                      | Maple and corn and/or cane pancake syrup blends (formerly Corn and maple syrup (2% maple))                        |
| Corn dog (frankfurter or hot dog with cornbread coating)           | Applesauce, stewed apples, unsweetened                                                               | Frosted Flakes, Kellogg's                                                                                         |
| Cracker, cheese                                                    | Chicken, breast, roasted, broiled, or baked, skin not eaten                                          | Strawberries, raw                                                                                                 |
| Salty snacks, corn or cornmeal base, corn chips, corn-cheese chips | Breakfast tart                                                                                       | Chocolate milk, ready to drink, low fat (1%)                                                                      |

|                                                                                 |                                                                       |                                                                          |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|
| Chicken, breast, roasted, broiled, or baked, skin not eaten                     | Egg omelet or scrambled egg, made with oil                            | Cake or cupcake, chocolate, devil's food or fudge, with icing or filling |
| Cookie, animal                                                                  | Pizza, cheese, prepared from frozen, thin crust                       | Rice, white, cooked, fat added in cooking, made with oil                 |
| Fruit flavored smoothie drink, frozen (no dairy)                                | Chicken or turkey teriyaki (chicken or turkey with soy-based sauce)   | Roll, white, soft                                                        |
| Cheeseburger with tomato and/or catsup, on bun                                  | Taco or tostada with meat                                             | Lemonade, fruit flavored drink                                           |
| Chicken patty, fillet, or tenders, breaded, cooked, from fast food / restaurant | Milk shake, fast food, chocolate                                      | Cheese, cream                                                            |
| Cookie, butter or sugar                                                         | Chicken nuggets                                                       | Queso Fresco                                                             |
| Ice cream cone, no topping, flavors other than chocolate                        | Ice cream cone, no topping, flavors other than chocolate              | Tea, iced, bottled, black                                                |
| Cheese, Parmesan, dry grated                                                    | Cracker, snack                                                        | Cookie, animal                                                           |
| Beef steak, broiled or baked, lean only eaten                                   | Cheese, Cheddar                                                       | Honey Nut Cheerios                                                       |
| Popcorn, popped in oil, unbuttered                                              | Water, bottled, sweetened, with low calorie sweetener                 | Pork sausage                                                             |
| Crackers, saltine                                                               | Pretzels, soft                                                        | Macaroni or noodles with cheese, made from packaged mix                  |
| Cereal, ready-to-eat, NFS                                                       | Meat and corn hominy soup, Mexican style, home recipe (Pozole)        | Pancake syrup, NFS                                                       |
| Applesauce, stewed apples, unsweetened                                          | Peanut butter                                                         | Soft drink, pepper type                                                  |
| Chicken patty, fillet, or tenders, breaded, cooked                              | Pediasure, infant formula, ready-to-feed                              | Hard candy                                                               |
| Mayonnaise-type salad dressing                                                  | Beef steak, broiled or baked, lean only eaten                         | Cookie, chocolate sandwich                                               |
| Chewing gum, regular                                                            | Fruit flavored drink, with high vitamin C, powdered, reconstituted    | Yogurt, fruit, low fat milk                                              |
| Egg, whole, fried with oil                                                      | Frosted Flakes, Kellogg's                                             | Corn dog (frankfurter or hot dog with cornbread coating)                 |
| Bread, wheat or cracked wheat, toasted                                          | Jambalaya with meat and rice                                          | Carrots, raw                                                             |
| Apple Jacks                                                                     | Popcorn, popped in oil, buttered                                      | Fruit flavored smoothie drink, frozen (no dairy)                         |
| Ice cream sandwich                                                              | Pizza, with meat other than pepperoni, from school lunch, thick crust | Cheerios                                                                 |
| Tortilla, flour (wheat)                                                         | Roll, white, soft                                                     | Italian dressing, made with vinegar and oil                              |
| Soft drink, cola, diet                                                          | Yogurt, frozen, flavors other than chocolate, NS as to type of milk   | Chocolate milk, ready to drink, whole                                    |
| Grape juice, 100%                                                               | Chocolate milk, made from syrup with whole milk                       | Chicken patty, fillet, or tenders, breaded, cooked                       |

|                                                                            |                                                                          |                               |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------|
| Margarine-like spread, tub, salted                                         | Strawberry milk, NFS                                                     | Cinnamon Toast Crunch         |
| Egg omelet or scrambled egg, made without fat                              | Frankfurter or hot dog sandwich, beef, plain, on white bun               | Lucky Charms                  |
| Pizza, cheese, from restaurant or fast food, thin crust                    | Milk shake, home recipe, flavors other than chocolate                    | Barbecue sauce                |
| Pinto, calico, or red Mexican beans, dry, cooked, fat not added in cooking | Shepherd's pie with beef                                                 | French toast, plain           |
| Soy sauce                                                                  | Frankfurter or hot dog sandwich, NFS, plain, on white bun                | Bread, garlic                 |
| Taco or tostada with meat                                                  | Fruit smoothie, bottled                                                  | Ice cream, regular, chocolate |
| Chicken, NS as to part and cooking method, NS as to skin eaten             | Chicken fillet (breaded, fried) sandwich with lettuce, tomato and spread | Egg, whole, fried with oil    |
| Marshmallow                                                                | Hot chocolate / Cocoa, made with dry mix and water                       | Lemonade, fruit juice drink   |
| Egg, whole, boiled or poached                                              | Strawberry milk, whole                                                   | Butter, stick, salted         |

## Appendix B: Aim 2 Supplementary materials

### B.1: Child focus group recruitment materials

*Tufts University invites your child to participate in...*

## A Focus Group about Processed Foods

### At West End House



We will be holding focus groups about processed foods. In order for your child to participate, please fill out the forms in this packet. To thank them for their time, children will receive a \$5 gift card to Target.



#### Your child can participate if:

- ✓ Your child is in the 4<sup>th</sup>, 5<sup>th</sup> or 6<sup>th</sup> grade OR between 6 and 9 years old
- ✓ Your child is able to speak and understand English

#### If your child would like to participate, please:

- ✓ Read and discuss the assent form with your child. If your child would like to participate, have them sign the assent form.
- ✓ Read and sign the parent permission form and fill out the attached survey.
- ✓ Return this packet to the West End House office or to Rachel Bleiweiss-Sande. You can also have your child give the forms to their classroom teacher.



**Tufts**  
UNIVERSITY

Gerald J. and Dorothy R.  
Friedman School of  
Nutrition Science and Policy

**For questions about the focus groups,  
please contact:**

Rachel Bleiweiss-Sande  
Doctoral Student  
510-334-3701

[rachel.bleiweiss\\_sande@tufts.edu](mailto:rachel.bleiweiss_sande@tufts.edu)

*B.2: Parent focus group recruitment materials*

*Tufts University invites you and your child to participate in...*

## **A Focus Group about Processed Foods**

**November 8<sup>th</sup>**

**3:30pm-4:30pm at the Whittier School**



We will be holding **two** focus groups about processed foods. One for kids, and one for parents. **We have space for only 8 people per focus group.**

The child and parent focus groups will take place at the **same time**. Healthy snacks will be provided!

To thank you for your time, parents will be given a **\$20 gift card to Target**. Your child will receive a **\$5 gift card to Target**.

### **You and your child can participate if:**

- ✓ Your child is in the 4<sup>th</sup>, 5<sup>th</sup> or 6<sup>th</sup> grade
- ✓ You and your child are able to speak and
- ✓ understand English



### **If you and your child would like to participate, please:**

- ✓ Read and discuss the assent form with your child. If your child would like to participate, have them sign the assent form.
- ✓ Read and sign the parent permission form, the parent consent form, and fill out the attached survey.
- ✓ Return the permission form and survey to the Whittier School office. You can also have your child give the forms to their classroom teacher.

**For questions about the focus groups,  
please contact:**



**Tufts**  
UNIVERSITY

Gerald J. and Dorothy R.  
Friedman School of  
Nutrition Science and Policy

Rachel Bleiweiss-Sande  
Doctoral Student  
510-334-3701

[rachel.bleiweiss\\_sande@tufts.edu](mailto:rachel.bleiweiss_sande@tufts.edu)

## *B.2: Guide for child focus groups*

**Target population:** 4<sup>th</sup> – 6<sup>th</sup> grade students

**Objective:** To explore children's perceptions and understanding of processed foods.

### **Part I: Introduction** Estimated time: 3 minutes

**(Make sure everyone is seated with a nametag on (first name only) so that you can call on people. The note taker will take notes based on the first name of the child.)**

Hello everyone! Thank you for taking the time to talk to us today. My name is Rachel and I'm a graduate student from Tufts University, and helping me out today is Paula, also from Tufts.

As you know, we're here to ask you about your thoughts about different foods. We're interested in how you, and other people your age, think about and talk about different foods. Your opinions and thoughts are really valuable to us, and we just ask that you be as honest as possible.

Before we begin, let's go over a few ground rules. We will not be using your names attached to anything that is said in this circle. We might share the things you say today with other university professors and people we work with, but we will never use your real name.

It's also important that you don't share what other people say in this circle today with anyone outside the circle. This includes telling other people who was in the group today and what they said.

Again, there are no right or wrong answers today. We want to hear what's on your mind and what you have to say. Please raise your hand whenever you want to speak and I will call on you. If you aren't talking very much, I may ask you to share your thoughts. Please do not interrupt each other. Everyone will get a chance to share.

Does anyone have any questions?

**Part II: Icebreaker** – the icebreaker is meant to get kids talking and make them feel comfortable. Estimated time: 5 minutes

To get us started and to get to know each other a little, we'd like to start by having everyone say their name and their favorite snack. I'll start – my name is Rachel, and my favorite snack is bananas and peanut butter. Who's next? Please raise your hand and I will call on you.

### **PART III: Definitions of processed foods**

Estimated Time: 10 minutes

**(Get the “definition cards” out and lay them in front of you on the table. They are in the same order as listed in the script below.)**

So as you know, we’re here to talk about what you think and know about foods today. We’re going to start out by talking about what some words mean to all of us. These are all words that can be used to describe foods. I have these words written on cards – I’ll hold up a card, and together, we’ll talk about what we think each one means. Remember, there are no right or wrong answers.

*[5 cards – “fresh food,” “man-made food,” “machine-made food,” “unprocessed food,” “processed food”]*

[Hold up the first card]

**3a. What does “fresh food” make you think of?**

Prompts:

- **What are some examples of “fresh foods?”**
- **What other words would you use to describe “fresh foods?”**

**3b. What does “man-made” make you think of?**

Prompts:

- **What are some examples of “man-made foods?”**
- **What other words would you use to describe “man-made foods?”**

**3c. How about machine-made foods?**

Prompts:

- **What are some examples of “machine-made foods?”**
- **What other words would you use to describe “machine-made foods?”**

**3d. How about unprocessed foods?**

Prompts:

- **What are some examples of “unprocessed foods?”**
- **What other words would you use to describe “processed foods?”**

**3e. And lastly, how about processed foods?**

## **PART IV – Classifying foods**

Estimated time: 10 minutes

**(Lay out the 6 “food cards” and lay them out on the table. Make sure everyone can see them. The order of the cards does not matter.)**

Great. Now we’ll move on to a card sorting exercise. I have 6 cards here, each with a different picture of a food. Together, I’d like us to sort these cards into three piles: one for foods that you think are **not at all processed or unprocessed**, one for foods that you think are **a little processed**, and one for foods that you think are **very processed**. We don’t have to have an equal number of cards in each pile. Remember, there is no right or wrong answer.

**4a. Let’s start with the unprocessed foods. Which cards would you put in the unprocessed pile?**

(let the kids chime in and choose, then follow-up with the next question.)

- **Could you tell me a bit about why these foods are unprocessed?**

**4b. Great. Let’s move on to the foods that are a little bit processed. Which cards would you put in the a bit processed pile?**

(let the kids chime in and choose, then follow-up with the next question.)

- **Could you tell me a bit about why these foods are a little processed?**

**4c. Great. Let’s move on to the foods that are very processed. Which cards would you put in the very processed pile?**

(let the kids chime in and choose, then follow-up with the next question.)

- **Could you tell me a bit about why these foods are very processed?**

## **Part IV - Perceptions about the health of processed foods**

Estimated time: 10 minutes

**(Keep the food cards in the sorted piles, and ask the kids about how healthy they think each food is. Start with the unprocessed pile first, then the “a little bit” processed pile, and then the very processed pile.)**

Now we’ll go back to these same foods we just looked at and talk about the health of these foods. Remember – there’s no right or wrong answer, I’m interested in your thoughts and opinions.

**5a. We'll start with the tomato. Can you tell me how healthy you think this food is?**

- Prompts
  - **Tell me more about that. Do you think the way the food is made changes how healthy it is?**

**5b. How about the canned tomatoes?**

**5c. How about the ketchup?**

**5d. How about the apple?**

**5e. How about the apple sauce?**

**5f. How about the apple juice?**

*[continue through each food, going from unprocessed to processed within each food type]*

## **Wrap Up**

Thank you so much for participating in our focus group today. It was great to learn more about your thoughts and knowledge about different foods. I want to ask you if there is anything else that you want to share about your experiences with food that you didn't get a chance to share today?

Thank you again for sharing your thoughts and knowledge with us. We're all finished for today.

[Ask the kids to line up and tell you their names to receive their gift card. Kids will initial on the prepared spreadsheet to show that they received their gift card]

### *B.3: Focus group guide for parent focus groups*

**Target population:** Parents of 4<sup>th</sup> – 6<sup>th</sup> grade students

**Objective:** To explore parent's perceptions and understanding of processed foods.

#### **Part I: Introduction**

Estimated time: 3 minutes

**(Make sure everyone is seated with a nametag on (first name only) so that you can call on people. The note taker will take notes based on the first name of the parent.)**

Hello everyone! Thank you for taking the time to talk to us today. My name is Rachel and I'm a graduate student from Tufts University, and helping me out today is Paula, also from Tufts.

As you know, we're here to ask you about your thoughts about different foods. We're interested in how you, and other parents like you, think about and talk about different foods. Your opinions and thoughts are really valuable to us, and we just ask that you be as honest as possible.

Before we begin, let's go over a few ground rules. We will not be using your names attached to anything that is said in this circle. We might share the things you say today with other university professors and people we work with, but we will never use your real name.

It's also important that you don't share what other people say in this circle today with anyone outside the circle. This includes telling other people who was in the group today and what they said.

Again, there are no right or wrong answers today. We want to hear what's on your mind and what you have to say. Please feel free to speak whenever you are inspired – you do not need to wait for me to address you. If you aren't talking very much, I may ask you to share your thoughts. Please do not interrupt each other. Everyone will get a chance to share.

Does anyone have any questions?

**Part II: Icebreaker** – the icebreaker is meant to get parents talking and make them feel comfortable. Estimated time: 5 minutes

To get us started and to get to know each other a little, we'd like to start by having everyone say their name and their favorite snack. I'll start – my name is Rachel, and my favorite snack is bananas and peanut butter. Who's next? Please jump in whenever you are ready.

### **Part III: Definitions**    Estimated time: 10 minutes

So as you know, we're here to talk about what you think and know about foods today. We're going to start out by talking about what some words mean to all of us. These are all words that can be used to describe foods. I have these words written on cards – I'll hold up a card, and together, we'll talk about what we think each one means. Remember, there are no right or wrong answers.

*[5 cards – “fresh food,” “man-made food,” “machine-made food,” “unprocessed food,” “processed food”]*

[Hold up the first card]

#### **3a. What does “fresh food” make you think of?**

Prompts:

- **What are some examples of “fresh foods?”**
- **What other words would you use to describe “fresh foods?”**

#### **3b. What does “man-made” make you think of?**

Prompts:

- **What are some examples of “man-made foods?”**
- **What other words would you use to describe “man-made foods?”**

#### **3c. How about machine-made foods?**

Prompts:

- **What are some examples of “machine-made foods?”**
- **What other words would you use to describe “machine-made foods?”**

#### **3d. How about unprocessed foods?**

Prompts:

- **What are some examples of “unprocessed foods?”**
- **What other words would you use to describe “processed foods?”**

#### **3e. And lastly, how about processed foods?**

### **Part III: Shopping/serving behavior**    Estimated time: 7 minutes

Great. Now I wanted to talk about what you think about when you're shopping for food for yourself and your children.

#### **4a. Let's start with snack foods. What are some examples of foods that you would buy or make for your 4<sup>th</sup> grader for a snack?**

**4b. What do you think about when you are choosing snacks for your 4<sup>th</sup> graders?**

Prompts:

- Is it health?
- What your 4<sup>th</sup> grader likes to eat?
- Convenience?
- Cost?

**4c. What foods would you choose for a healthy snack?**

Prompts:

- What about these foods makes them healthy?

**4d. Which foods do you choose for a special snack that might not be as healthy?**

Prompts:

- What makes them special?
- What makes them unhealthy?
- 

**4e. Which foods do you choose if you need something that's convenient?**

Now, thinking about foods you would choose for yourself for a snack, how are they different than what you would choose for your 4<sup>th</sup> grader?

**4f. Great. Thinking about other meals, what would you consider to be a healthy dinner for your 4<sup>th</sup> grader? It could be a meal from a restaurant, prepared at home, or something you eat at home.**

Prompts:

- What about the meal makes it healthy to you?

**4g. Now what about if you were having a celebration meal for your 4<sup>th</sup> grader. What foods would be different?**

Prompts:

- Would you still consider these foods healthy? Why or why not

**Part V: Classifying processed foods:** Estimated time: 7 minutes

Great. Now I wanted to talk about how we classify different foods. I have a bunch of pictures of foods from the supermarket here (fresh tomato, canned tomatoes, ketchup, white bread, whole wheat bread, oat groats, rolled oats, instant oatmeal, apple, applesauce, sweetened apple juice). We can define these foods as unprocessed, moderately processed (or somewhat processed), and highly processed (show cards with these words written on them).

**5a. Which of these foods do you think about as unprocessed?**

- Could you tell me a bit about what makes them unprocessed?

**5b. Great. Let's move on to the foods that are moderately processed. Which foods do you think about as moderately processed?**

- Could you tell me a bit about what makes them moderately processed?

**5c. Great. Let's move on to the foods that are highly processed. Which of these foods do you think about as highly processed?**

- Tell me about what makes them seem highly processed to you?

**Part VI: Perceptions about the health of processed foods** Estimated time:  
10 minutes

Now we'll go back to these same foods we just looked at and talk about the health of these foods. Remember – there's no right or wrong answer, I'm interested in your thoughts and opinions.

**6a. We'll start with the tomato. Could you tell me about your thoughts on the healthfulness of the tomato?**

**6b. How about the canned tomatoes?**

Prompts:

- Tell me more about that. Do you think the way the food is made changes how healthy it is?

**6c. How about the ketchup?**

**6d. How about the apple?**

**6e. How about the applesauce?**

**6f. How about the apple juice?**

*[continue through each food, going from unprocessed to processed within each food type]*

**Part VII: Wrap-Up**

Thank you so much for participating in our focus group today. It was great to learn more about your thoughts and knowledge about different foods. Before we finish, I want to ask you if there is anything else that you want to share about your experiences with food that you didn't get a chance to share today?

Thank you again for sharing your thoughts and knowledge with us. We're all finished for today.

**Part VIII: Gift-cards**

Take out the spreadsheet with gift card numbers written down. Have everyone initial/sign their name and give them a gift card. Tell everyone that they can take fruit/a Kind bar home with them if they like.

*B.4: Activity cards for child and parent focus groups*



## Appendix C: Aim 3 Supplementary materials

### *C.1: Sensitivity analysis, analytic approach*

Sensitivity analysis assessing the impact of two approaches the analysis of the relationship between processing level and Healthy Eating Index 2015 score among children participating in the Summer Foodservice Study (N=131)<sup>a</sup>

|             | Repeated measures approach |      |          |        |        | Survey weights approach <sup>b</sup> |      |          |        |        |
|-------------|----------------------------|------|----------|--------|--------|--------------------------------------|------|----------|--------|--------|
|             | $\beta$                    | SE   | <i>p</i> | 95% CI |        | $\beta$                              | SE   | <i>p</i> | 95% CI |        |
| Unprocessed | *0.287                     | 0.04 | 0.00     | 0.202  | 0.371  | *0.286                               | 0.04 | 0.00     | 0.205  | 0.368  |
| Basic       | 0.026                      | 0.05 | 0.63     | -0.077 | 0.128  | 0.008                                | 0.05 | 0.87     | -0.090 | 0.107  |
| Moderately  | -0.051                     | 0.05 | 0.32     | -0.151 | 0.049  | -0.045                               | 0.05 | 0.41     | -0.151 | 0.062  |
| Highly      | *-0.213                    | 0.04 | 0.00     | -0.290 | -0.137 | *-0.200                              | 0.04 | 0.00     | -0.270 | -0.129 |

<sup>a</sup> Adjusted for maternal education level and days of National School Breakfast and National School Lunch Program participation.

<sup>b</sup> Consumption data from three, non-consecutive 24-hr recalls, equal weighting between recalls

\* Significant association,  $p < 0.001$

### C.2: Sensitivity analysis, weighting approach

Sensitivity analysis assessing the impact of two weighting schemes for recall day in the analysis of the relationship between processing level and Healthy Eating Index 2015 score among children participating in the Summer Foodservice Study (N=131)<sup>a</sup>

|             | Weighted by day of week <sup>b</sup> |      |          |        |        | Equal weighting between recalls <sup>c</sup> |      |          |        |        |
|-------------|--------------------------------------|------|----------|--------|--------|----------------------------------------------|------|----------|--------|--------|
|             | $\beta$                              | SE   | <i>p</i> | 95% CI |        | $\beta$                                      | SE   | <i>p</i> | 95% CI |        |
| Unprocessed | *0.307                               | 0.04 | 0.00     | 0.223  | 0.390  | *0.286                                       | 0.04 | 0.00     | 0.205  | 0.368  |
| Basic       | 0.031                                | 0.07 | 0.63     | -0.098 | 0.161  | 0.008                                        | 0.05 | 0.87     | -0.090 | 0.107  |
| Moderately  | -0.059                               | 0.07 | 0.37     | -0.189 | 0.070  | -0.045                                       | 0.05 | 0.41     | -0.151 | 0.062  |
| Highly      | *-0.226                              | 0.04 | 0.00     | -0.300 | -0.152 | *-0.200                                      | 0.04 | 0.00     | -0.270 | -0.129 |

<sup>a</sup> Adjusted for maternal education level and days of National School Breakfast and National School Lunch Program participation.

<sup>b</sup> Consumption data from three, non-consecutive 24-hr recalls, weighted by weekday vs. weekend

<sup>c</sup> Consumption data from three, non-consecutive 24-hr recalls, equal weighting of each recall

\* Significant association,  $p < 0.001$

### C.3: Mediation analysis

Summary of mediation analysis assessing HEI<sup>a</sup> score as a mediator in the relationship between percentage of calories from unprocessed/minimally processed foods<sup>9</sup>, highly processed foods<sup>9</sup>, and BMI-z<sup>b</sup> score among children participating in the Summer Foodservice Program Study (N=131)

|                                     | $\beta$ | 95% CI |       | $p$  |
|-------------------------------------|---------|--------|-------|------|
| Unprocessed/minimally               |         |        |       |      |
| Indirect effect                     | -0.003  | -0.006 | 0.001 | 0.13 |
| Direct effects                      | 0.008   | -0.003 | 0.019 | 0.13 |
| Total effects                       | 0.005   | -0.005 | 0.016 | 0.31 |
| Proportion of total effect mediated | -0.51   | 1.20   | 0.06  | -    |
| Ratio of indirect to direct effect  | -0.34   | 2.00   | 0.05  | -    |
| Ratio of total to direct effect     | 0.66    | -1.67  | 0.84  | -    |
| Highly processed                    |         |        |       |      |
| Indirect effect                     | 0.001   | -0.001 | 0.004 | 0.27 |
| Direct effects                      | -0.003  | -0.012 | 0.007 | 0.58 |
| Total effects                       | -0.001  | -0.011 | 0.008 | 0.67 |
| Proportion of total effect mediated | 0.86    | 0.09   | 0.50  | -    |
| Ratio of indirect to direct effect  | 0.46    | 0.08   | 0.57  | -    |
| Ratio of total to direct effect     | 0.54    | 0.92   | 1.14  | -    |

<sup>a</sup> Healthy Eating Index 2015

<sup>b</sup> Age- and sex- standardized body mass index