COMPENSATION EFFECT BETWEEN SODIUM AND FAT IN REDUCED AND LOWER FAT PROCESSED FOOD SYSTEMS

BY

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DISSERTATION

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ABSTRACT

Dietary sodium reduction is of concern to the scientific community due to it being a contributing factor in hypertension in adults in the United State (US). Processed foods are a significant contributor towards dietary sodium consumption. Obesity has also been linked to the increased incidence and prevalence of hypertension. With obesity and dietary sodium consumption being leading factors in the management of hypertension, processed foods that are lower in both fat and sodium for increased consumer acceptance require examination.

The overall objectives of this study were to: 1) analyze sodium and fat content in ten major processed food categories, 2) survey consumer knowledge of sodium and fat content in processed foods in order to assess comprehension of nutrient content claims, 3) determine drivers of liking of a model processed food system with varying levels of sodium, fat, and herb levels, 4) compare the link among prior perception of nutrition labels, sensory acceptability, and nutrition labeling formats in a model processed food system., and 5) determine the threshold of sodium in a model reduced and low oil-in-water emulsion system.

From the major processed food categories in which sodium and fat content were examined, the salad dressings and deli meats categories showed a significant ($p \leq 0.05$) increase in sodium for the reduced fat product when compared to its regular counterpart. When consumer knowledge of sodium and fat content was surveyed, less than 50% of the consumers were able to correctly answer questions of nutrient content claims pertaining to sodium and fat. Particularly, for health and food professionals, nutrition professionals had the highest percentage of correct responses, and medical professionals had the lowest percentage of correct responses in nutrient content claim knowledge. When a model processed food system was tested for consumer liking, sodium and herb levels were found to be the drivers of liking when sodium, fat, and herb levels

were varied. When evaluating prior perception of nutrition labels and sensory acceptability, consumer sensory acceptability was not impacted by the presentation of nutrient content information with the sample tasting. However, presenting labeling information without an actual sample tasting did impact the expected consumer acceptability. The threshold for sodium was identified in a model reduced and low oil-in-water emulsion system, and was found to be higher in the reduced fat emulsion than the low fat emulsion. Study findings allow for insight regarding consumers' detection of differences in sodium levels within reduced and low fat emulsion systems, which can contribute towards achieving mechanisms for stealth sodium reduction in processed food systems.

Overall, findings from this research can be used to guide product formulation for reducing sodium content without compromising consumer acceptance, particularly in reduced and lower fat processed food systems. Maintaining consumer acceptance in lower sodium and fat food systems compared to their original counterparts would contribute towards a decrease in the risks associated with hypertension in the U.S.

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Chapter 1: Introduction

1.1 Research Background

Hypertension afflicts over 78 million adults in the US (Vasan, 2002; Go and others, 2013), among which over 70% are either overweight or obese (Jeffery and others, 1983; Wofford, 2008). Hypertension increases morbidity and mortality from coronary heart disease, stroke, congestive heart failure, and end-stage renal disease (Whelton and others, 2002). Treatment for the medical management of hypertension includes the use of anti-hypertensive drugs, including diuretics and beta blockers. Treatment for the medical nutrition therapy of hypertension includes 1) a weight reduction equal to or greater than 10% of current body weight and 2) a reduction in dietary sodium (Whelton and others, 2002; Mahan and others, 2012).

Research studies have demonstrated a strong relationship between dietary sodium intake and hypertension, resulting in recommendations to limit dietary sodium intake (Loria and others, 2001; Graudal, 2005; Bayer and others, 2012). The Dietary Guidelines for Americans recommend a daily sodium intake of less than 2,300 mg/day for the healthy populous, whereas dietary sodium intake is recommended to be less than 1,500 mg/day for at risk groups, such as: 1) individuals with hypertension, diabetes, or chronic kidney disease, 2) individuals who are 51 years of age and older, and 3) African Americans (IOM, 2010). Thus, the daily sodium recommendation of 1,500 mg or less is applicable to half of the US population (USDA, 2010).

In 2008, Congress requested that the Institute of Medicine of the National Academies (IOM, 2010) propose strategies for reducing dietary sodium intake in an effort to recommended levels in the Dietary Guidelines for Americans. In its 2010 report "Strategies to Reduce Sodium in the United States," the IOM recommended as a primary strategy that the United States Food and Drug Administration (FDA) set mandatory national standards for sodium content in foods, and modify the currently GRAS (Generally Recognized as Safe) classification of sodium that had been set in 1958. This primary strategy was based on the conclusions that excess salt intake is a major public health problem, and that voluntary initiatives within the past 40 years have failed to reduce salt intake. Therefore, IOM recommended that focusing on processed foods are the best strategy to protect the public health since most salt consumed is in said processed foods sold to consumers. The IOM (2010) noted four particular areas that required further research: 1) understanding how salty taste preferences develop throughout the lifespan; 2) developing innovative methods to reduce sodium in foods while maintaining palatability, physical properties, and safety; 3) enhancing current understanding of factors that impact consumer awareness and behavior relative to sodium reduction; and 4) monitoring sodium intake and salt taste preference.

As an interim strategy in 2010, the IOM encouraged the food industry to voluntarily reduce the sodium content in advance of the implementation of mandatory standards (IOM, 2010). Supporting strategies included that government agencies, public health and consumer organizations, and the food industry execute activities to support the reduction of sodium levels in the food supply and support consumers in reducing sodium intake. Additional strategies included that federal agencies ensure and enhance monitoring and surveillance relative to sodium intake measurement, salt taste preference, and sodium content of foods (Bibbins-Domingo and others, 2010; IOM, 2010; Palar and others, 2009; Smith-Spangler and others, 2010). Three main principles towards sodium reduction in food products have been categorized as: 1) chemical stimulation to increase the saltiness perception peripherally, 2) cognitive mechanisms towards increasing awareness or shifting the saltiness preference, and 3) designed product structures that attempt to optimize the delivery of salt to the taste buds (Busch and others, 2013).

1.2 Research Rationale and Significance

Sodium content in processed food systems is a prominent issue in the food industry according to research studies highlighting the connection between hypertension and dietary sodium intake (Loria and others, 2001; Bayer and others, 2012). With the medical nutrition therapy for hypertension being a decrease in body weight and dietary sodium, the relationship between sodium and fat content in reduced and lower fat processed foods warrants examination. Reduced and lower fat foods that have higher sodium content compared to traditional counterparts may provide a compensatory effect, in which decreased levels of one nutrient are able to maintain consumer acceptance as a result of the increase of the other nutrient. Major processed food categories warrant further investigation in order to see if there is a compensation effect between sodium and fat. Consumer awareness of nutrition labels and health claims associated with certain processed foods can assess whether increased understanding of nutrient content interpretation is needed, since education regarding the compensation effect will require even greater awareness. Sensory evaluation of model processed food systems is necessary to identify at what levels of sodium and fat the compensation effect is displayed, and how consumer acceptance is impacted by the compensation effect.

This line of research is novel due to the fact that it highlights the compensation effect that occurs between sodium and fat in several processed food products, an issue not thoroughly examined in efforts for sodium reduction. Study findings are consistent with the recommended line of sodium reduction strategies by IOM. Findings will assist the IOM in further recommendations to Congress.

1.3 Overall Goal and Central Hypothesis

The overall goal of this research was to assess factors that impact consumption of sodium and fat in processed food systems. This long-term goal can be achieved through examining consumer knowledge and sensory evaluation of sodium and fat content in processed food systems. The central hypothesis of this dissertation was that, due to the compensation effect that occurs between sodium and fat in a model processed food system, decreased levels of fat does not significantly lower consumer acceptance as a result of the increase in sodium. Furthermore, decreased levels of both fat and sodium reduces consumer acceptance in processed food systems. The compensation effect can be defined as the increase in sodium that occurs when fat is decreased in a food product in order to maintain consumer acceptance of the product.

1.4 Outline of the Dissertation - Specific Research Aims, Hypotheses, and Approaches

To investigate the central hypothesis, five specific aims were developed. Specific research aim one (Chapter 3) examined sodium and fat content in ten major processed food categories. Specific objectives were to: 1) determine the relationship between sodium and fat content in food categories having both a regular and reduced fat counterpart and 2) determine sodium content of lower fat food categories. When investigating this specific aim, it was hypothesized that processed foods that are reduced in fat content would either have an increased sodium content than the regular fat counterpart or a sodium content higher than the Dietary Guidelines recommendations. To test this hypothesis, nutrition information from ten major processed food categories was collected and sodium and fat content were analyzed and compared.

In specific aim two (Chapter 4), consumer knowledge of sodium and fat content in processed foods were surveyed in order to assess comprehension of nutrient content claims. Specific objectives were to 1) compare the knowledge base of consumers with regard to nutrient content claims and recommended dietary intake, specifically for sodium, fat, and sugar, 2) compare the knowledge base of targeted health and food professionals for nutrient content claims and recommended dietary intake, specifically for sodium, fat, and sugar, 3) compare specified health conditions and concern of nutrient consumption and purchasing intent for sodium and fat. While investigating this specific aim, several working hypotheses were proposed. Based on this investigation, it was hypothesized that consumers are not knowledgeable (less than 50% correct response rate) on nutrient content claims pertaining to sodium and fat. It was also hypothesized that, based on current requirements for nutrition education, medical professionals, foodservice professionals, and food scientists are not knowledgeable on nutrient content claims pertaining to sodium and fat. In addition, it was hypothesized that concern of nutrient consumption and purchasing intent is highest among individuals with health conditions related to overconsumption of sodium and fat. To test these hypotheses, an online survey was conducted and analyzed.

In specific aim three (Chapter 5), drivers of liking of a model processed food system with varying levels of sodium, fat, and herb levels were identified. Specific objectives were to: 1) identify drivers of liking of a model processed food system with varying levels of sodium, fat, and herb levels, 2) compare overall liking of a model processed food system with varying sodium, fat, and herb levels, and 3) determine sensory attributes of a model processed food system with varying sodium, fat, and herb levels. When investigating this specific aim, several working hypotheses were proposed. It was hypothesized that the increase in sodium content when fat content is decreased results in a compensatory effect in which consumer acceptance is not impacted due to the increase in sodium levels when fat content is decreased. It was also hypothesized that the inclusion of herbs can contribute to an increase in overall liking in reduced and lower sodium and fat products. To test these hypotheses, a model processed creamy tomato soup with varying sodium, fat, and herb levels was developed, and consumer testing and descriptive analysis were conducted in order to identify drivers of liking.

In specific aim four (Chapter 6), the link between prior perception of nutrition labels, sensory acceptability, and nutrition labeling formats in a model processed food system was compared. Specific objectives were to: 1) determine prior perceptions of nutrition labels, 2) evaluate the influence of nutrition labels on sensory acceptability in a model processed food system, and 3) determine effective label formats by comparing verbal and visual labels. When investigating this specific aim, several working hypotheses were proposed. It was hypothesized that a significant interaction exists across prior perception of nutritional information on labels, sensory acceptability, and nutritional labeling format. It was also hypothesized that the effectiveness of nutritional labeling at influencing consumers' food choices will depend on the label format. To test these hypotheses, a model processed creamy tomato soup with varying sodium and fat levels was developed, and consumer testing was conducted.

In specific aim five (Chapter 7), mechanisms of sodium and fat reduction in processed food systems were identified by measuring the threshold of sodium in a model reduced and low oil-in-water emulsion system. When investigating this specific aim, it was hypothesized that threshold will be affected by fat content in a model emulsion system, and as fat content is increased, detection of sodium is decreased. To test this hypothesis, threshold testing was conducted and analyzed utilizing the R-index measure.

Finally, Chapter 8 summarizes all research findings in the preceding chapters. Future directions are proposed in this chapter.

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Chapter 2: Literature review

2.1 Introduction

Dietary sodium consumption is a major concern both in the United State and worldwide. The average estimated daily consumption of dietary sodium for all Americans ages 2 years and older is over 3400 mg according to the 2009-10 National Health and Nutrition Examination Survey (CDC, 2010). This intake is far more than the recommended daily intake of 2300 mg set by the 2010 Dietary Guidelines for Americans (USDA, 2010). Over 77% of the average American's daily sodium consumption has been contributed to processed foods (CDC, 2010).

Excessive consumption of dietary sodium has been linked to the increase in adults with hypertension both in the US and worldwide. Over 78 million US adults are impacted by hypertension, and over 90% of US adults will develop hypertension in their lifetime (Go and others, 2013). Elevated blood pressure is the leading contributor of cardiovascular disease, and has been linked to 62% of strokes and 49% of coronary heart disease worldwide (He and others, 2009).

The leading factor attributed to hypertension is overweight, with over 70% of hypertensive adults being overweight or obese (Wofford and others, 2008). Increased consumption of dietary sodium through processed foods is an additional factor (Whelton and others, 2002). The reduction of sodium from food products poses considerable challenges for the food industry. The reduction or replacement of sodium in food systems causes a significant impact on many facets of the food system, including sensory properties, which impacts consumer acceptance. To further address the nutrition needs of hypertensive individuals, examining methods for both fat and sodium content in food systems also poses to be a very complex and challenging problem (Kim and others, 2012).

2.2 Functions of Sodium

Sodium has played an important role in the history of civilization. It also has numerous uses and functions in the human body and in food systems. Salt (of which 40% is sodium chloride), has had significant historical importance. It served as a unit of exchange, and was commonly used for tax purposes due to its universal usage and value (Beauchamp, 1987). Salt was one of the most traded commodities in the world, and was used as a form of currency for goods and services (Durack and others, 2008).

Sodium is essential for the normal physiological function of human beings, and is the most prevalent cation in extracellular fluid. Sodium is necessary for a variety of biological functions, including nerve conduction, acid-base balance, muscle contraction, and for maintenance of blood pressure (Beauchamp, 1987). Human requirements for sodium or chloride must be obtained through the diet (Durack and others, 2008).

Sodium has been used as a classic method of food preservation (Durack and others, 2008). Sodium serves as an effective preservative because it reduces the water activity of foods, which consequently decreases the amount of unbound water available for microbial growth (Fennema, 1996). Sodium plays a role in the development of physical properties of foods that contribute to their noted attributes, such as baked goods, meats, and cheeses (Hutton, 2002; Desmond, 2007; Guinee and others, 2007). One of the most important roles of sodium in processed foods is its contribution to the sensory profile of foods. Sodium contributes to the enhancements of all tastes in addition to saltiness, and enhances overall flavor (Gillette, 1985).

2.3 Sodium Taste Transduction

The only compounds that taste primarily salty to humans are those that contain sodium or lithium, though other minerals (potassium and calcium) can have a salty component to their taste

(Van der Klaauw and others, 1995; Tordoff, 1996a). Among compounds that contain sodium, sodium chloride is the saltiest (Schiffman and others, 1980). Saltiness is primarily a function of the Na^+ cation, though the anion of the salt influences taste (Bartoshuk, 1980).

The principal mechanism for transduction of the salty taste involves passage of sodium through a specific ion channel in the apical membrane of receptor cells (Beauchamp, 1997). Taste transduction of NaCl takes place throughout the oral cavity, including taste papillae found on the tongue. Taste buds, found within papillae, contain taste receptor cells (McCaughey and others, 1997). Taste receptor cells are able to interact with tastes at their apical ends when sodium ions dissolved in the saliva bind (Chandrashekar and others, 2010). The entry of sodium from the outside to the inside of the taste receptor cell increases the membrane potential of the cell's interior relative to the outside. This depolarization leads to the release of neurotransmitters that transmits a signal to the brain to recognize the taste as salty (McCaughey and others, 1997).

Specific transduction mechanisms for salty compounds have not yet been determined for humans. However, rodents express epithelial sodium channels (ENaCs) that selectively allow the passage of sodium ions into taste tissue (McCaughey and others, 1997). The primary transduction events for salty taste transduction remain to be determined (McCaughey and others, 1997).

The unknown complexity of taste transduction for saltiness is a major factor in the difficulty in finding an acceptable substitute for salt (Mattes, 1997). Taste transduction for saltiness involves the passage of sodium ions through a narrowly gated ion channel. Therefore, it is difficult to find another substance to mimic the passage of sodium ions, except for toxic lithium ions (McCaughey and others, 1997).

2.4 Consumption and Recommendations for Sodium Intake in American Adults

The average estimated daily consumption of dietary sodium is over 3400 mg for all Americans ages 2 years and older (Figures 2.1 and 2.2). Based on the recommendations set by the Institute of Medicine Panel on Dietary Reference Intakes (DRI) for Electrolytes and Water in 2005, the Tolerable Upper Intake Level (UL) for sodium in adults is 2,300 mg/day. The UL, a category of Dietary Reference Intakes, is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects for almost all healthy individuals in the specified life stage group. For children younger than age 14 years, the UL is less than 2,300 mg/day (IOM, 2010).

The Adequate Intake (AI) for individuals ages 9 years and older is less than 1,500 mg/day. The AI, another DRI category, is the amount of a nutrient recommended for a life stage or gender group for which it is established (IOM, 2005). Several significant studies have supported the AI recommendation for sodium (Table 2.1). The Dietary Guidelines for Americans, based on the IOM Panel on Dietary Reference Intakes, recommends a daily sodium intake of less than 2,300 mg/day. Dietary sodium intake is recommended to be less than 1,500 mg/day for at risk groups, which is applicable to half of the US population (USDA, 2010). At risks groups include the following three populations: 1) individuals with hypertension, diabetes, or chronic kidney disease, 2) individuals who are 51 years of age and older, and 3) African Americans. Several studies suggest that older adults and African Americans have a heightened sensitivity to sodium, which contributes to increased blood pressure (Weinberger and others, 1986 and 1991; Ishibashi and others, 1994). The interaction of environmental facts upon genetic factors has been noted to play a role in hypertension among African Americans (Duru and others, 1994).

2.5 Hypertension

Hypertension, also known as high blood pressure, is a condition in which the pressure of blood flowing through the arteries is too high. Blood pressure is read by two measures, systolic blood pressure and diastolic blood pressure. Systolic is the measurement while the heart is pumping. Diastolic is the measurement between beats (Bakris, 2012). Hypertension is measured as a systolic pressure higher than 120 mmHg and a diastolic pressure higher than 80 mmHg. The diagnosis is confirmed after consistent readings have been taken by a Medical Doctor (MD).

Hypertension is the second leading modifiable cause of death, accounting for an estimated 395,000 yearly preventable deaths in the United States (Danaei and others, 2009). It is estimated that one third of US adults have hypertension, and another third of US adults have pre-hypertension (IOM, 2010). Estimates place the direct and indirect costs of hypertension at $73.4 billion in 2009 (IOM, 2010).

There are two types of hypertension, and they are defined by their etiology. Primary (or essential) hypertension is the most common form and represents 90% of hypertension diagnoses. Essential hypertension has no identifiable cause, and develops gradually over many years. Secondary hypertension is more acute due to various conditions and medications (Bakris, 2012). Treatment for the medical management of hypertension has been the implementation of anti-hypertensive drugs, including diuretics, beta blockers, vasodilators, and calcium channel blockers (Mahan and others, 2004).

2.6 History of the Relationship between Sodium and Hypertension

The concern with elevated sodium in the diet, and the relationship between dietary sodium consumption and hypertension has been a controversial topic spanning over a century.

The earliest study that reported a positive correlation between salt intake and blood pressure in humans was published in 1904. This study was both confirmed and refuted over the next 30 years by several scientists (Ambard, 1904; Lowenstein 1907; Graudal, 2005).

The therapy of sodium reduction in the treatment of hypertension was highlighted by Dr. Wallace Kempner (Kempner, 1948). In the study, hypertensive patients were treated with a low-salt diet. Additional population studies were conducted by Dr. Lewis Dahl, who argued that the development of hypertension depends on both the individual's genetic background and environmental factors. He also noted that high salt intake was more dangerous in infants, and recommended that no salt should be added to baby foods (Dahl, 1972).

In 1969, the White House held its first Conference on Food, Nutrition, and Health, where the salt content of infant food became a key focus of the conference (Mayer, 1969). The National Academy of Sciences committee convened in 1970 to further evaluate the safety of salt levels in infant food, and found the evidence against salt to be inconclusive. The committee found "no valid scientific evidence" to suggest that salt in baby food contributed to the development of hypertension later in life, and no evidence of a limit on dietary sodium. Throughout the next forty years, clinical trials and meta-analyses reported on the relationship between dietary sodium consumption and hypertension and whether or not a link exists between the two (Loria and others, 2001; Bayer and others, 2012).

2.7 Scientific Studies that Support the Relationship between Sodium and Hypertension

2.7.1 Animal, Genetic, Epidemiological, and Migration Studies

There is a significant scientific body of evidence that has linked excess sodium intake in the pathogenesis of elevated blood pressure (Appel and others 2011). Numerous animal studies have demonstrated the role that sodium plays in the regulation of blood pressure (Denton and others, 1995; Elliott and others, 2007). Additionally, higher sodium intake in the animal models has subsequently shown an increase in blood pressure. Though genetic causes of high and low blood pressure are rare, human genetic studies have also examined the importance of sodium intake in the regulation of blood pressure (Lifton and others, 1996 and 2001).

Several larger epidemiological studies have examined the influence of sodium intake on blood pressure in specific communities. One of the largest epidemiological studies (INTERSALT) that examined sodium intake and blood pressure among 52 communities concluded that there was a positive relationship between the two. Additionally, the study concluded that there was a positive relationship between sodium intake and the increase in blood pressure as age increases (INTERSALT, 1988). It was estimated that an increase of 6 grams/day in sodium intake over a 30 year period would lead to an increase in systolic blood pressure by 9 mm Hg. Migration studies, in which communities who consume lower quantities of sodium are migrated to an urban environment with an increased sodium intake, have also demonstrated a subsequent rise in blood pressure (He and others, 1991; Poulter and others, 1990).

2.7.2 Intervention Studies

Several population-based intervention studies have demonstrated a decreased in blood pressure as a result of decreased sodium intake. One of the most successful intervention studies was conducted in two rural villages in Portugal. At the time of the study, Portugal had the highest stroke rate in Europe, and average daily salt intake was 360 mmol per person (Forte and others, 1989). Each village had a population of 800. One village was provided education on methods in which to reduce dietary salt intake, and the other village was considered to be the control group. Through the education, the intervention village was able to reduce dietary salt intake by 50%. In the intervention village, the average blood pressure fell by 3.6/5.0 mmHg at the end of the first year, and by 5.0/5.1 mmHg at the end of the second year. (Forte and others, 1989). Another study conducted in two rural communities in Japan concluded that a decrease in sodium intake (2.3 g/day) led to a decrease in systolic blood pressure by 3.1 mm Hg (Takahashi and others, 2006). The study examined 550 subjects in two total villages in north-eastern Japan between 40-69 years of age. One group received dietary education regarding methods to decrease sodium intake and increase the intake of fruits and vegetables, while the other groups was considered to be the control group. At the end of one year, systolic blood pressure decreased from 127.9 to 125.2 mm Hg in the intervention group, and increased from 128.0 to 128.5 mmHg in the control group.

2.7.3 Clinical Studies

Several prominent clinical trials strengthen the evidence on the effects of sodium on blood pressure (He and others, 2009). Several similarities can be noted for these dose-response trials. Each of these trials tested at least 3 sodium levels, and each documented statistically significant dose-response relations. The lowest level of sodium intake in each trial was ~1500 mg/d, which is consistent with the level recommended by the Dietary Guidelines for Americans (He and others, 2009).

One dose-response trial which studied 20 hypertensive patients over a course of 4 months reported a reduction in blood pressure by 16/9 mmHg. Mean age of the patients was 57 years old, with a range of 42 to 72 years old. The mean blood pressure of the patients was 164/101 mmHg, and the mean 24-hour urinary sodium excretion was 162 mmol (range 58-296). Patients were instructed to reduce their daily sodium intake to between 30-50 mmol (3 grams salt) for the duration of one month. Patients then entered a 3-month double-blind study of three levels of sodium intake (200 mmol, 100 mmol, 50 mmol). After the 3 month period, the average decrease in blood pressure from the highest to lowest sodium intake was 16/9 mmHg (MacGregor and others, 2001).

Another clinical trial examined 46 subjects with varying blood pressure levels were placed on four sodium treatments (50, 100, 200, and 300 mmol/day). The subjects had a mean age of 69 years old, and were placed into 3 groups based on systolic (SBP) and diastolic (DBP) blood pressure reading : 1) SBP >160 mmHg and DBP <90 mmHg, 2) DBP >90 mmHg, and SBP <160 mmHg and DBP <90 mmHg. Following diagnostic classification, all participants were started and maintained on a 50 mmol/day sodium diet for the duration of the study. Each sodium treatment lasted for 2 weeks, and there was a 2-week washout period in between each treatment. Analysis concluded that systolic blood pressure increased significantly with increasing salt dosage across all three groups. The highest increase was from the group who had a systolic blood pressure greater than160 mmHg and a diastolic blood pressure of less than 90 mmHg. The next increase was from the group having a diastolic blood pressure of over 90 mmHg, followed by the group with a systolic blood pressure less than 160 mmHg and a diastolic blood pressure less than 90 mmHg. (Johnson and others, 2001).

The largest clinical trial, the Dietary Approaches to Stop Hypertension (DASH)-Sodium trial, was designed to assess the effects of both the DASH diet and reduced sodium intake on blood pressure. A secondary study to the DASH diet trial (Taubes, 1997), study subjects were assigned either the DASH diet, which consisted of 10 servings of fruits and vegetables and 2 servings of low fat dairy, or a typical American diet. Subjects were also assigned 3 levels of sodium (50, 100, 150 mmol based on a 2100 calorie diet) for 30 days while consuming either diet. The highest sodium level reflected typical consumption in the US, and the intermediate level was the upper limit of current national recommendations (Sacks and others, 2001). Within each diet, there was a general pattern such that the lower the sodium level, the greater the mean reduction in BP. Sodium reduction from 100 to 50 mmol generally had twice the effect on BP as reduction from 150 to 100 mmol (Vollner and others, 2001).

The DASH-Sodium trial also documented that reduced sodium intake significantly lowered BP in each of the major subgroups studied (age, ethnicity, hypertension status). Within the control diet, the reduction in blood pressure was significant from the higher to lower sodium levels. The reduction in blood pressure ranged from 5-8 mmHg systolic and 2-4 mmHg diastolic for the control diet. For the DASH diet, there was a further 50% reduction in blood pressure (Bray and others, 2004). The DASH-Sodium trial also demonstrated the effect of sodium intake on age, and concluded that sodium reduction to a level of 1500 mg/day lowers blood pressure more in older adults versus younger adults. Study results showed a decrease in systolic blood pressure by 8.1 mmHg in individuals between 55-76 years old, compared with a decrease in systolic blood pressure by 4.8 mmHg in individuals between 23-41 years old. In individuals without hypertension, study results showed a decrease in systolic blood pressure by 7.0 mm Hg in individuals greater than45 years of age compared with 3.7 mm Hg in individuals less than45 years of age (Bray and others, 2004). With 90% of adults eventually becoming hypertensive, these results demonstrated that sodium reduction can lessen the rise in BP with age. (Sacks and others, 2010)

A meta-analysis of clinical trials demonstrated that a moderate reduction in sodium intake caused significant decrease in blood pressure in both hypertensive and normotensive individuals

(He and others, 2002). The meta-analysis included 17 trials in 734 hypertensive adults, and 11 trials in 2220 normotensive adults. The median age of the hypertensive individuals studied for the trials were 50 years old, with the range between 24-73 years old. The study duration of these trials ranged from 4 weeks to 1 year (median was 6 weeks). The median blood pressure on usual salt intake was 150/93 mmHg, and the median 24-hour urinary sodium on the usual salt intake was 9.5 grams of salt/day. The median 24-hour urinary sodium on the reduced salt intake was 5.1 grams of salt/day. The median age of the normotensive individuals studied for the trials were 47 years old, with the range between 22-67 years old. The study duration of these trials ranged from 4 weeks to 3 years (median was 4 weeks). The median blood pressure on usual salt intake was 127/78 mmHg, and the median 24-hour urinary sodium on the usual salt intake was 9.1 grams of salt/day. The median 24-hour urinary sodium on the reduced salt intake was 4.8 grams of salt/day. The pooled estimates of reduction in blood pressure from salt intake were 4.96/2.73 +/- 0.40/0.24 mmHg in hypertensive individuals ($p<0.001$ for both systolic and diastolic) and 2.03/0.97 +/- 0.27/0.21 mmHg in normotensive individuals ($p<0.001$ for both systolic and diastolic). Furthermore, statistical analysis showed a dose-response between the change in urinary sodium and blood pressure. It was concluded that a reduction in 6 grams of salt/day predicted a fall in blood pressure of 7.11/3.88 mmHg in hypertensive individuals and 3.57/1.66 mmHg in normotensive individuals (He and others, 2002).

2.8 Recommendations for Sodium Reduction in Processed Food Systems

In 2008, Congress requested the Institute of Medicine of the National Academies (IOM, 2010) to propose strategies for reducing dietary sodium intake to levels recommended in the Dietary Guidelines for Americans. In its 2010 report "Strategies to Reduce Sodium in the United States," the IOM recommended as a primary strategy the United States Food and Drug

Administration (FDA) set mandatory national standards for sodium content in foods, and modify the currently GRAS (Generally Recognized as Safe) classification of sodium that had been set in 1958. This primary strategy was based on the conclusions that excess salt intake is a major public health problem, voluntary initiatives within the past 40 years have failed to reduce salt intake, and that processed foods are the best strategy to protect the public health since most salt consumed is in foods sold to consumers. The IOM noted four particular areas that required further research: 1) understanding how salty taste preferences develop throughout the lifespan; 2) developing innovative methods to reduce sodium in foods while maintaining palatability, physical properties, and safety; 3) enhancing current understanding of factors that impact consumer awareness and behavior relative to sodium reduction; and 4) monitoring sodium intake and salt taste preference.

As an interim strategy, the IOM encouraged the food industry to voluntarily reduce the sodium content in advance of the implementation of mandatory standards. Supporting strategies included that government agencies, public health and consumer organizations, and the food industry execute activities to support the reduction of sodium levels in the food supply and support consumers in reducing sodium intake. Additional strategies included that federal agencies ensure and enhance monitoring and surveillance relative to sodium intake measurement, salt taste preference, and sodium content of foods. Three main principles towards sodium reduction in food products have been categorized: 1) chemical stimulation to increase the saltiness perception peripherally, 2) cognitive mechanisms towards increasing awareness or shifting the saltiness preference, and 3) designed product structures that attempt to optimize the delivery of salt to the taste buds (Busch and others, 2013).

2.8.1 Mechanisms of Sodium Reduction in Processed Food Systems

Methods currently utilized to optimize the perception of saltiness include salt enhancers and salt replacers (Durack and others, 2008). Salt enhancers are ingredients that enhance the perception of saltiness. Examples of salt enhancers include glycine, glycerine monoethyl ester, L-lysine, L-argine, lactates, mycoscent, trehalose, L-ornithine, o-aminoacyl sugars, alapyridaine, and glutamates (Kilcast, 2007).

Salt replacers are ingredients in which the sodium cation has been replaced by ions including potassium, calcium or lithium. The most widely used salt replacer in the food industry is potassium chloride (Durack and others, 2008). Though a potassium substitution of up to 30% has been utilized in food products, the development of bitter or metallic off flavors have been reported in food products (Kilcast and others, 2007). Additionally, higher intakes of potassium are not recommended for individuals with specific health conditions, including diabetes, kidney disease, and heart disease (USDA, 2005).

Additional replacers for sodium reduction include the use of herbs and spices. Herbs and spices can contribute to flavor, color and texture of food products (Ainsworth and others, 2007). Food manufacturers have followed IOM recommendations and have reduced sodium content in foods. This has been accomplished with and without the utilization of sodium substitutes and enhancers (IOM, 2010).

2.8.2 Consumer Acceptability of Sodium Reduction in Processed Food Systems

Processed food choices account for over 77% of the average American's daily sodium consumption (CDC, 2010). Though sodium is widely present in all foods, 44% of sodium consumption comes from the following 10 food categories: breads, deli meats, pizza, poultry, soups, sandwiches, cheeses, savory snacks, and pasta and meat mixed dishes (CDC, 2012).

The acceptance of reduced-sodium foods has been slow, as taste is the major factor in food choice in the U.S. (Mattes, 1997; IOM, 2010). Research has indicated that sensory preferences for sodium can be decreased (Mattes, 1997). Increased acceptance of reduced sodium foods has been reported to coincide with long-term adherence (8-12 weeks) to a reduced sodium diet (Mattes, 1997). One study examined liking for 10 processed foods having a “regular” and “reduced sodium” version (bread, cheese, chicken broth, crackers, canned green beans, margarine, peanuts, potato chips, tuna, and vegetable juice). For a 4 month period, 8 subjects followed a reduced-sodium diet. At the end of the study, there was no significant difference in liking between the “regular” and “reduced sodium” foods (Mattes, 1997).

Additional studies also demonstrated that a change in preference to reduced sodium foods is gradual and takes 2 to 4 months to accomplish (Bertino and others, 1983; Teow and others, 1984; Elmer and others, 1985; Blais and others, 1986). Though acceptability of reduced sodium food products has coincided with duration of exposure, studies have shown that a reduction in sodium up to 20% is undetectable by human taste receptors (Durack and others, 2008). As a result of various studies, the IOM recommends a gradual and monitored reduction of sodium in the food supply (IOM, 2010).

2.9 Fat: Functions of and Mechanisms of Taste Perception

Dietary fats are essential in providing energy and supporting cell growth to the body (American Heart Association, 2014). Dietary fats also aid in the absorption of some nutrients and in the production of certain hormones, assist in protecting various organs, and contribute to body warmth. Fats affect flavor perception in foods through several sensory attributes, including aroma, taste, and mouth feel. They also serve as carriers for lipophilic flavor compounds in foods, such as long-chain fatty acids and aliphatic aldehydes (Mela, 1994).

Research studies have examined the issue of fat as being one of the primary tastes, and the role that free fatty acids may play in taste perception. Evidence supporting a taste component for dietary fat has prompted study of plausible transduction mechanisms. One of the roles by which free fatty acids may have an involvement in taste transduction through taste cell depolarization of delayed rectifying potassium channels (Mattes, 2009). Another study examined that free fatty acids found in food may play an important direct role in taste perception. Cis-polyunsaturated fatty acids were found to inhibit delayed-rectifying potassium channels. Saturated, monounsaturated, and trans-polyunsaturated fatty acids were concluded to have no significant effect on potassium currents (Gildertson and others, 1997).

Several studies which evaluated the effects of oil on human taste perception provided varying conclusions regarding the influence of fat composition on taste. One study examined three oils (tuna oil, soybean oil, high oleic corn oil) possessing different fatty acid compositions for taste intensity. The oils did not affect taste intensity for sweetness or saltiness, decreased taste intensity for sourness or bitterness, and increased for umami (Koriyama and others, 2002). This study implies that fats may have an impact on several of the human tastes, including saltiness perception.

Another study investigated lipid variation and intensity of saltiness perception in a model processed emulsion system. When overall liking and saltiness perception was examined in ranch salad dressings with varying lipid compositions (olive, soy, canola, vegetable, almond, soy+canola+olive oil combo), there was no significant difference in overall liking or saltiness perception among the salad dressings with the exception of the salad dressing with olive oil (Cox and others, 2015). Research regarding the role of lipids and taste perception remains limited.

2.10 Scientific Studies that Support the Relationship between Weight and Hypertension

Obesity has been linked to the increased incidence and prevalence of hypertension, with over 70% of hypertensive individuals being either overweight or obese (Wofford and others, 2008). The prevalence of overweight and obesity has progressively increased throughout the past several decades. The prevalence of obesity (body mass index ≥30 kg/m^2) for U.S. adults aged 20 to 74 years old increased from 13.4% to 30.9% from 1960 to 2000 (Neter and others, 2003). More than one-third (35.7%) of adults are considered to be obese (NHANES, 2010). Additionally, the prevalence of overweight or obese (body mass index ≥25 kg/m^2) for U.S. adults was 68.8% (NHANES, 2010).

It has been discussed that obesity impacts several body mechanisms and influences metabolic changes, including activating the sympathetic nervous and renin-angiotensin systems, causing insulin resistance and hyperinsulinemia, and altering intrarenal vascular resistance (Hall, 1997). These changes have been related to enhanced renal tubular sodium reabsorption and sodium retention (Luft and others, 1997). It has been hypothesized that overweight and obese individuals may have an increased sensitivity to sodium. In a study of 60 obese and 18 non-obese adolescents, blood pressure was more affected by dietary sodium intake in obese than non-obese adolescents. Furthermore, this increased sensitivity to sodium was reduced after weight loss Rocchini and others, 1989).

Research studies have supported that weight loss is an effective means in the primary treatment of hypertension (Neter and others, 2003; Gillum and others, 1983; Eliahou and others, 1981). One of the earliest meta-analysis of 31 epidemiological studies published between 1923 and 1967 concluded that increased weight is associated with an increase in blood pressure

(Chiang and others, 1969). Furthermore, an additional meta-analysis of 19 clinical observations published between 1918 and 1952 concluded that weight reduction lowers blood pressure in a significant number of obese hypertensive patients (Chiang and others, 1969). Another meta-analysis of 12 studies published from 1954 to 1985 concluded that a decrease in body weight by 1 kilogram resulted in a reduction in systolic blood pressure by 1.2 mmHg and a reduction in diastolic blood pressure by 1.0 mmHg (Staessen and others, 1988). A more recent meta-analysis examined 25 randomized clinical trials published between 1978 and 2002 with a total of 4874 subjects showed a 5 kilogram reduction in body weight resulted in a blood pressure reduction of 4.4/3.6mmHg (Neter and others, 2003).

One of the first long-term clinical trials conducted to examine the significance of weight reduction in the management of blood pressure is the Trials of Hypertension Prevention (TOHP). The study involved 2250 men and women (age range of 30-54 years old) with a high-normal diastolic blood pressure (83-89 mmHg), a systolic blood pressure < 140 mmHg, and a body mass index that is 110-165% of desirable body weight (26.1-37.4 kg/m^2 for men and 24.4-37.4 kg/m^2 for women). Study participants were randomly assigned to 1 of 4 treatment groups: weight loss only, sodium reduction only, weight loss plus sodium reduction, or no active intervention. Study participants were followed up for 36 to 48 months. Study outcomes concluded that, compared with the usual care group, blood pressure decreased 3.7/2.7 mmHg in the weight loss group, 2.9/1.6 mmHg in the sodium reduction group, and 4.0/2.8 mmHg in the combined group at 6 months ($p<0.001$). At 36 months, blood pressure decreased 1.3/0.9 mmHg in the weight loss group, 1.2/0.7 mmHg in the sodium reduction group, and 1.1/0.6 mmHg in the combined group. After 48 months, the incidence of hypertension was significantly less in all of the intervention groups versus the usual care group.

One of the more prominent clinical trials, the DASH diet, demonstrated that a lower fat diet contributed to a reduction in blood pressure as much as a single drug therapy (Taubes, 1997). The study, which was a total of 11 weeks, included 459 adults with a systolic blood pressure between 140-159 mmHg and a diastolic blood pressure between 90-99 mmHg. For the first 3 weeks, all study participants ate a control diet, which was considered to be a typical US diet. Following the control diet, study participants were randomized into 3 groups and ate one of three diets for an additional 8 weeks. One group continued to eat the control diet, and another group was fed a diet with increased (8.5) servings of fruits and vegetables. The third group ate the DASH diet, which was lower in saturated fat, included 2 servings of low-fat dairy, and had increased (10) servings of fruits and vegetables. The diet with increased fruits and vegetables resulted in a 2.8 mmHg systolic reduction and a 1.1 mmHg diastolic reduction in blood pressure. The DASH diet produced significant results, with a 5.5 mmHg systolic reduction and a 3.0 mmHg diastolic reduction in blood pressure. Additionally, for those study participants whose blood pressure was in the highest range, study results showed a 11.4 mmHg systolic reduction and a 5.5 mmHg diastolic reduction (Taubes, 1997). Though prevalence of overweight or obesity was not accounted for in study subjects, study results demonstrated the significance of a low-fat diet in the treatment of hypertension.

2.11 Relationship between Fat Content and Saltiness Perception in Food Systems

There are a number of studies that have investigated the relationship between fat content and perception of saltiness in food products, most commonly sausages and dairy products. Studies which examine the relationship between the two have contradicting opinions. Several studies have concluded that an increase in fat content leads to an increase in saltiness perception, including dairy products, cheeses, and sausages (Panouille and others, 2011; Phan and others, 2008; Ruusunen and others, 2001).

In the studies examining cheese and dairy products, the fat was replaced with water in the lower fat formulations. This replacement resulted in a lower concentration of sodium in the aqueous phase. It has been shown that higher concentrations of sodium in the aqueous phase leads to an increased salty perception (Shamil and others, 1992). Therefore, a lower concentration of sodium in the aqueous phase could consequently contribute to a decreased perception of saltiness in lower fat products.

In the studies examining dairy products and sausages, fat was replaced with protein in lower fat varieties. The higher protein content results in a lower concentration of sodium in the aqueous phase, which decreases saltiness perception in higher protein and lower fat samples (Ruusunen and others, 2001).

Other studies have concluded that an increase in fat content leads to a decrease in saltiness perception in food products. One study that examined saltiness perception in regular and reduced fat frankfurters noted a decrease in saltiness perception as the fat content was increased (Hughes and others, 1997). Some studies involving cheeses and sausages have reported no relationship between fat content and saltiness perception (Ventanas and others, 2010; Lauverjat and others, 2009).

The lack of agreement on the effect of fat content on sodium perception in various food products indicates that other components and variables have an impact on perception of saltiness. Additional factors could include how the sodium is released from the product, and how the sodium is available in the mouth to be perceived (Kuo and others, 2014). As a hydrophobic substance, fat can serve as a barrier against sodium migration and can make it difficult for sodium to be released from a food matrix (Hughes and others, 1997). Furthermore, fat has been shown to coat the tongue surface, thus hindering the availability of sodium to the taste buds (Lynch and others, 1993). However, other studies as describe above have shown that certain components of fat may sensitize taste receptor cells, which would result in a higher response towards sodium (Gilbertson and others, 2005; Mattes, 2009).

2.12 Conclusions

Dietary sodium reduction, specifically in processed foods, is of concern to the scientific community due to its link in decreasing both the incidence and prevalence of hypertension in U.S. adults. Though hypertension should be a concern to all U.S. adults, the majority of hypertensive individuals are overweight or obese. Therefore, both fat and sodium consumption and reduction warrant examination.

Though research indicates the majority of dietary sodium consumption stems from 10 major processed food categories, further research regarding the quantity of sodium in reduced and lower fat foods could assist in determining the relationship between sodium and fat in processed food products. Sodium reduction in processed food products have proven difficult due to the prominent role that sodium plays in sensory properties of foods. The lack of agreement on the effect of fat content on perception of saltiness in various food products demonstrates that this is an area in which much research is still required. Sensory evaluation of food products reduced in sodium and fat could assist in the identification of factors that impact both sodium and fat consumption.

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2.14 Tables and Figures

Table 2.1: Studies that Support Limiting Sodium to Less than 1,500 milligrams a Day

Study **Lead Author** **Publication** **Date/Citation**	**Description**	**Conclusion**	**Strengths**	**Limitations**
Dietary reference intakes for water, potassium, sodium, chloride, and sulfate. *The National Academies Press* 2005	A 600-plus-page book from the Institute of Medicine that analyzed research on optimal water, potassium, sodium, chloride and sulfate levels.	Identified 1,500 mg/day as the adequate intake level of sodium for adults, and 2,300 mg/day as an upper level intake.	One of the most complete reviews of the scientific evidence for goal-setting of potassium, sodium, chloride, sulfate and water intake.	Based on a review of existing data
The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke. A call for action from the American Heart Association. Appel LJ *Circulation* 2011;123:1138-1143	This advisory supplemented the AHA's original policy paper (Lloyd-Jones DM et al, Circulation. 2010;121:586-613), with a focus on justification of the AHA's recommendation for intake of dietary sodium.	The scientific evidence indicates that the dietary sodium limit of <1,500 mg per day is associated with a decreased risk of cardiovascular disease, stroke and kidney disease.	Experts in the basic, clinical and population sciences present a thoughtful analysis of sodium reduction as it relates to cardiovascular disease. Several authors also participated in the AHA's overall goals paper.	Based on a review of existing data

Table 2.1 (continued)

Study **Lead Author** **Publication** **Date/Citation**	**Description**	**Conclusion**	**Strengths**	**Limitations**
Reduced dietary salt for the prevention of cardiovascular disease: a meta-analysis of randomized controlled trials. Taylor RS *Am J Hypertens.* 2011;24:843-853	This meta-analysis examined trends for CVD events and all-cause mortality in 7 randomized controlled trials that had tested the efficacy of a sodium reduction intervention.	One trial conducted in extremely sick patients with heart failure had little or no relevance for the general population. In five trials, the number of events was lower among those consuming less sodium. In one trial, the number of cardiovascular events was similar among participants with lower and higher sodium intakes.	The analysis included seven trials.	Because the heart failure trial included patients who already were sick and on medications that effect sodium balance, results can't be applied to general population. The remaining six trials were analyzed separately for those with high and normal BP. As a consequence, the power to recognize a statistically significant effect of sodium reduction on CVD risk was extremely limited. Subsequent analysis (see He FJ, below) that excluded the heart failure trial and pooled data from the remaining trials identified a statistically significant 20% decrease in CVD events among the lower-sodium group.

Table 2.1 (continued)

Study Lead Author Publication Date/Citation	**Description**	**Conclusion**	**Strengths**	**Limitations**
Long-term effects of dietary sodium reduction on cardiovascular disease outcomes: observational follow-up of the Trials of Hypertension Prevention (TOHP). Cook NR *BMJ* 2007;334:885-892	This long-term, follow-up study included data from two previous randomized controlled clinical trials to examine the long-term effects of reduced sodium consumption on cardiovascular events among adults 30-54 with high blood pressure.	Sodium reduction was associated with an approximately 25% reduction in the risk of cardiovascular events.	The results were analyzed according to the participant's original randomized assignment (lower sodium intake or usual care) and events were tracked over a prolonged period of time (10-15 years), increasing the statistical power to recognize an effect of sodium reduction on CVD morbidity and mortality	Incomplete follow-up rate; questionnaire format rather than direct measurement of blood pressure, weight, and sodium intake.
Salt reduction lowers cardiovascular risk: meta-analysis of outcome trials. He FJ *Lancet* 2011;378:380-382	The paper is a quantitative assessment of the clinical trials in the study by Taylor, et. al. 2011	Investigators reported a statistically significant 20 percent decrease in cardiovascular events among the lower-sodium group.	In six trials, there was a reduction in clinical outcomes (all-cause mortality, cardiovascular mortality and events)	One trial, which examined heart failure, affected results due to participants being severely salt and water depleted

Figure 2.1: Estimated Mean Daily Sodium Intake by Age and Ethnicity, National Health and Nutrition Examination Survey (NHANES), 2009-2010

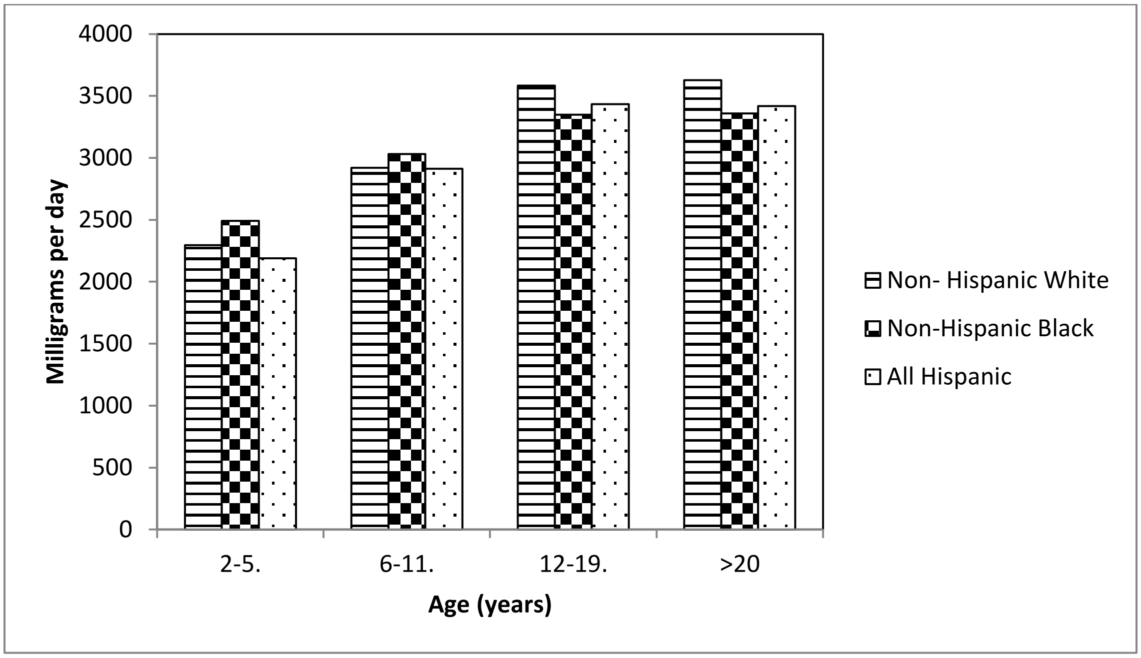
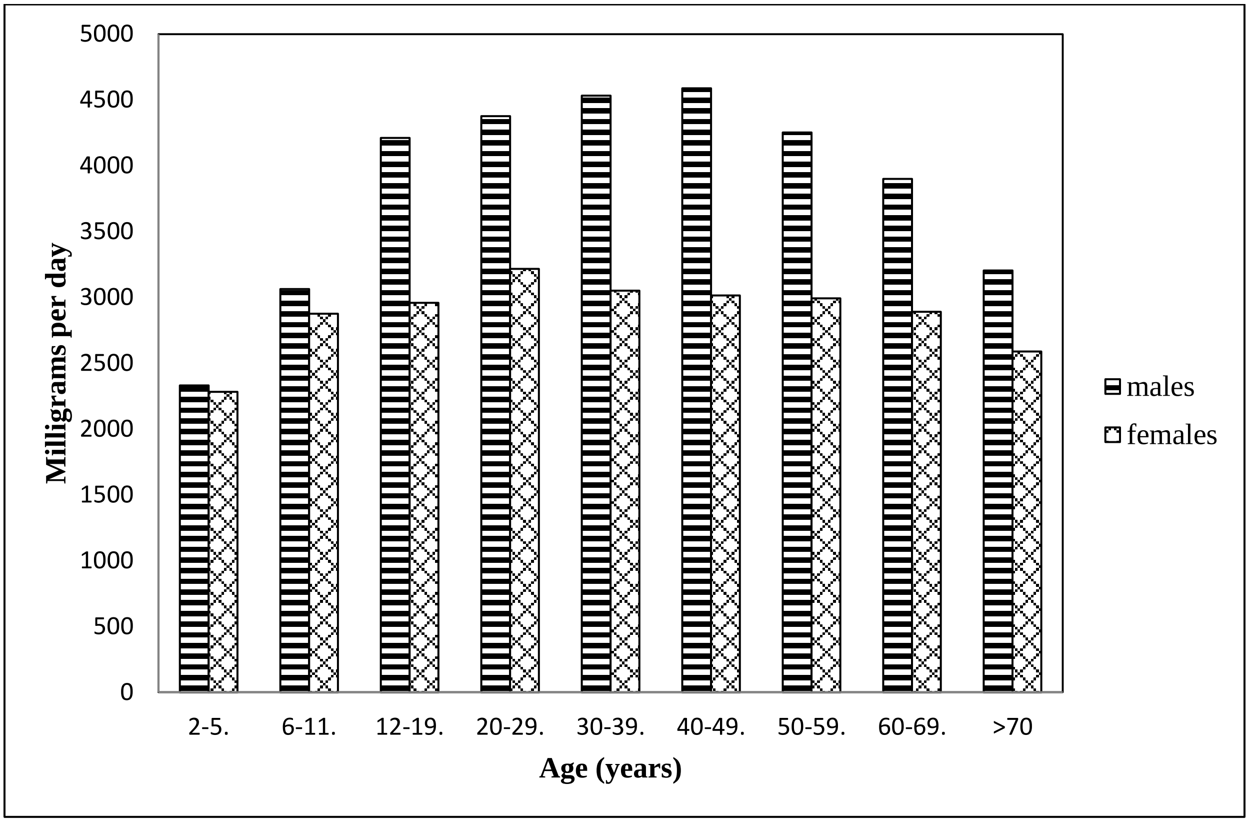


Figure 2.2: Estimated Mean Daily Sodium Intake by Age and Gender, National Health and Nutrition Examination Survey (NHANES), 2009-2010



Chapter 3: Trends in Sodium and Fat Content in Processed Foods: A Grocery Inventory Study

3.1 Abstract

Hypertension affects approximately one third of adults in the United States. Major factors attributed to hypertension are being overweight or obese and an increased consumption of dietary sodium through processed foods. Individuals can reduce their risk of hypertension by consuming foods that are both lower in fat and sodium. The objectives of this research were to: 1) determine the relationship between sodium and fat content in food categories having both a regular and reduced fat counterpart and 2) determine sodium content of lower fat food categories. Categories investigated were soups, frozen dinners, canned beans, canned vegetables, salad dressings, cereals, tomato products, breads, deli meats, and snack foods. Nutrition information was collected at five local grocery stores in the United States Central Illinois region over an 8-month period. Specific nutritional areas of interest in this study included calories, fat, and sodium. From the ten categories examined, the salad dressings and deli meats categories showed a statistically significant ($p < 0.05$) increase in sodium for the reduced fat product when compared to its regular counterpart. The soups category showed a statistically significant decrease in sodium for the reduced fat product versus the regular fat product. The snack foods (i.e., potato chips) category showed a decrease in sodium for the reduced fat product versus the regular counterpart. Five lower fat categories examined (canned beans, canned vegetables, cereals, breads, tomato products) had an average sodium content of 150-400 mg/serving. The availability of food products that meet sodium and fat reduction needs of hypertensive individuals could impact the health status of these individuals. Consumer knowledge of the nutrition facts labels and claims regarding sodium should also be assessed. Comprehension of

nutrition labels could assist consumers in making food choices that can positively impact their health status.

Key Words: sodium, fat, labels, nutrition, hypertension, processed

3.2 Introduction

The concern over dietary sodium consumption in processed foods has stemmed from the increased incidence and prevalence of hypertension in US adults (IOM, 2010). One-third of American adults have hypertension, and another third of American adults have pre-hypertension (Roger and others, 2012). Adults in the United States consume over 3400 mg of dietary sodium on a daily basis (Levings and others, 2012), far more than the recommended daily consumption of 2300 mg set by the 2010 Dietary Guidelines for Americans (USDA, 2010). Additionally, at-risk groups, including individuals with hypertension, African Americans, and middle aged and older adults, are recommended to consume no more than 1500 mg of sodium daily (USDA, 2010). These at-risk groups now constitute approximately 69% of the US adult population (CDC, 2009). Though dietary sodium consumption through processed food systems has been linked to hypertension, studies have examined that both weight loss and decreased dietary sodium consumption are key factors in the nutritional treatment of hypertension (Loria and others, 2001; Wofford, 2008).

Over 77% of dietary sodium consumed comes from processed foods (Mattes and Donnelly, 1991), and the majority of sodium added during commercial processing is added as sodium chloride (Fregly, 1983; Mattes, 1991; IOM, 2010). Foods eaten at home constitute roughly 63% of sodium intake, and include processed foods, prepared frozen meals and dishes, and carryout foods obtained from restaurant or foodservice operators (USDA, 2011).

A survey conducted by the National Health and Nutrition Examination Service (NHANES) examined 11 food categories for their contribution to daily dietary sodium intake. Food categories included mixed dishes, meat and meat alternatives, legumes, grains, fruit, vegetables, sweets, beverages, salty snacks, milk, and condiments and fats and oils. Mixed dishes, including pasta and other entrees, consisted of 44% of total daily sodium intake out of the 11 food categories. Meat and meat alternatives were 15.5% of total daily sodium intake. Grains, including bread, cereal, and rice, totaled 11.4% of total daily sodium intake. Vegetables were 9.3% of total daily sodium intake. The remaining categories (sweets, condiments, salty snacks, milk, beverages, beans, and fruit) totaled less than 5% of daily dietary sodium intake (IOM, 2010). Another survey conducted by NHANES in 2007-2008 identified the top 10 ranked food categories contributing to sodium consumption. The food categories selected was based on analyzing 100 food categories. The top ten categories were breads, cold cuts, pizza, fresh and processed poultry, soups, sandwiches, cheese, pasta mixed dishes, meat mixed dishes, and savory snacks (USDA, 2011).

Consumption of food products meeting recommended dietary sodium intakes remains a challenge in processed food products. With recommended intakes ranging from 1500 mg to 2300 mg per day, food products recognized as ‘healthy’ should contain no more than 480 mg of sodium per serving, or no more than 600 mg for packaged meals and main dishes (IOM, 2010). Additionally, several processed food categories display a higher quantity of sodium in reduced and lower fat versions than in the regular fat version. In the reduction of sodium alone in processed food products, past voluntary efforts by food manufacturing companies to reduce sodium levels in foods have posed a challenge (IOM, 2010). With taste being a primary determinant of food choice, consumers have not been willing to purchase lower sodium food products because they are not perceived to be as palatable as their original sodium level counterparts (IOM, 2010). With fat being another nutrient that impacts taste, increasing sodium levels when fat levels are reduced may compensate for taste.

The overall goal of this study was to examine sodium and fat content in ten major processed food categories. In order to accomplish this goal, the specific objectives were to: 1) determine the sodium content of selected lower fat processed food categories, 2) determine the relationship between sodium and fat content in selected processed food categories having both a regular and reduced fat counterpart. Our working hypothesis was that processed foods that are reduced in fat content would have increased sodium content in order to compensate for taste. We also hypothesized that lower fat food categories would have greater than 500 mg of sodium per serving, which would be higher than the recommended guidelines (IOM, 2010).

3.3 Materials and Methods

3.3.1 Materials

Ten processed food categories were investigated: soups, frozen dinners, canned beans, canned vegetables, salad dressings, cereals, tomato products, breads, lunch meats, and snack foods. Soups, frozen dinners, salad dressings, deli meats, and snack foods (potato chips, chips, tortilla chips, 100 calorie snack packs) were compared for the relationship between sodium and fat content in their regular fat versus reduced and lower fat counterparts. Canned beans, canned vegetables, cereals, tomato products, breads, and select categories of snack foods (pretzels, popcorn, nuts, trail mix, beef jerky, rice snacks) were examined for sodium content only, as these categories did not have varying levels of fat.

3.3.2 Methods

Nutritional Facts labels on both brand name and private label products were evaluated. Nutrition information was collected for the food categories previously listed (Appendix A). In addition, brand information, flavor information, serving size, number of servings, calories, calories from fat, total fat, sodium, fiber, sugars, carbohydrates, potassium, and protein were also collected. Nutrition information was recorded manually from the label, and entered into Microsoft excel spreadsheet. Products were purchased from five local grocery stores in the United States Central Illinois region, including Target, WalMart, Schnuck's, County Market, and Meijer. Nutrition information was collected over an 8-month period.

3.3.3 Statistical Analysis

Data were analyzed using Microsoft Excel. Independent samples t-test was conducted to compare mean sodium content between regular and reduced fat food products, and the calculated probabilities obtained from the analysis were compared to the significance level at 5%.

3.4 Results and Discussion

A summary of nutrition information collected for all the categories is provided in Table 3.1. For example, the salad dressings category had a total of 350 nutrition labels collected, and serving size ranged from 30-34 g. Of the 350 labels collected, 224 contained a regular fat content. From the 224 regular fat labels, 8 listed or contained a sodium content that would meet a claim, including 'low sodium.' Of the 350 labels collected, 126 listed or contained a reduced or lower fat content that would meet a claim, including 'reduced fat,' 'less fat,' or 'fat free.' Fourteen out of the 126 reduced or lower fat labels listed or contained a sodium content that would meet a claim, including 'low sodium' and 'very low sodium'. The same line of information is presented in Table 3.1 for other categories.

<u>Categories with Increased Sodium in Reduced or Lower Fat Counterparts</u>

For the salad dressings category, no trend was shown between sodium and fat when comparing the mean sodium content per serving of the regular (284 mg) versus the reduced (304 mg) fat labels across all salad dressing flavors. However, when three salad dressing flavors were compared, there was a significant difference ($p < 0.001$) in the sodium content of the regular (267 mg) versus the reduced (331 mg) fat ranch salad dressing labels (Table 3.2). With the variety of salad dressing flavors and ingredients used to develop each flavor, sodium content of salad dressing could be based on consumer acceptance specific to the flavor. However, current sodium levels of reduced fat ranch salad dressing, if lowered, may not be detectable by consumers. When difference threshold was compared between garlic-flavored and pepper-flavored mashed potato model food systems, there was no significant difference between the difference thresholds of the two (Laurila and others, 1996), which may be applicable to salad dressing.

The deli meats category did not display any trend between sodium and fat when comparing the regular (480 mg of sodium) and the reduced (483 mg of sodium) fat labels. However, when separated out by two brands, there was a significant difference ($p < 0.001$) between the sodium content of the regular (Brand A = 326 mg, Brand B = 618 mg) and reduced (Brand A = 511 mg, Brand B = 434) fat labels (Table 3.2).

The 100 calorie snack pack category (snack foods category) showed a significant difference ($p < 0.05$) in sodium content when comparing the sodium content of the regular (109 mg) versus reduced fat (197 mg) levels. Sodium is a significant contributor towards the sensory properties of foods (Hutton, 2002). Increased sodium in reduced and lower fat processed food products may contribute towards a compensation effect, in which increased sodium levels are adjusted to compensate for decreased taste and flavor due to a reduction in fat content.

Categories with Decreased Sodium in Reduced or Lower Fat Counterparts

Two categories, soups and frozen dinners, showed a simultaneous decrease in sodium and fat. For the soups category, when comparing the mean sodium content per serving of the regular (771 mg) versus the reduced and lower fat (639 mg) labels, there was a significant difference ($p < 0.001$) between the sodium content of the two (Table 3.2). Though the sodium in soups was decreased in the lower fat labels, the sodium content is still high at an average of 639 mg, according to the 2015 Dietary Guidelines recommendations. Sodium is a significant sensory component of soups, and enhances the overall flavor of the soup by enhancing the taste and flavor of other ingredients (Hutton, 2002), thereby making sodium reduction in soups is a hurdle. When comparing the sodium content per serving of the regular (887 mg) versus the lower (585 mg) fat labels within the frozen dinners category, there was a significant difference ($p < 0.001$) between the sodium content of the two (Table 3.2).

Categories with No Changes in Sodium in Reduced or Lower Fat Counterparts

For the potato chips (snack foods) category, there was no significance between the sodium content of the regular (203 mg) versus reduced (181 mg) fat labels. Additionally, for chip types other than potato chips (snack foods category), there was no difference in the sodium content of the regular (241 mg) versus reduced (235 mg) fat labels. No relationship was shown between sodium and fat in the rice cakes (snack foods) category when comparing the mean sodium content of the regular (228 mg) versus the reduced (133 mg) fat labels. When comparing the mean sodium content per serving of the regular (497 mg) versus reduced fat (476 mg) labels in the tomato products category (pasta sauce), there was no significant difference in sodium content.

Food categories which showed a trend with increased sodium content in reduced fat versions also showed a different trend when separated by flavor, type, or brand. The salad dressings category, when separated by French and Italian flavors, showed no difference in sodium content of regular and reduced fat labels (Table 3.2). When comparing type of deli meats (turkey, chicken, ham), there was no difference in sodium content of the regular and reduced fat labels. The frozen dinner category, which showed a decrease in sodium content when fat was also decreased when separated by one brand, showed no difference between sodium and fat when separated by another brand (Table 3.2).

Categories which Examined Sodium Content Only

Food categories which were examined for sodium content only also highlighted several findings. The breads category, the most commonly consumed category (USDA, 2011), had a mean sodium content of less than 200 mg/serving. With breads being a commonly consumed category, multiple servings would quickly impact the overconsumption of dietary sodium intake. Several studies have shown that reduced sodium content in bread is associated with a corresponding decrease in consumer acceptance (Salovaara and others, 1982; Helleman and others, 1990; Zandstra and others, 2000). However, reductions of 10-20% and a gradual reduction up to 50% have been shown to not significantly impact overall liking (Rodgers and others; Girgis and others, 2003; Bolhuis and others, 2011).

The cereals category had a mean sodium content of 198 mg/serving. According to industry standards, up to 2% of salt is added to cereals in order to create a balance with the sweet taste found in cereals. (Fast and others, 1990). With cereals being consumed primarily for breakfast, overconsumption of dietary sodium intake may not be an issue. Canned beans had an average sodium content of 443 mg/serving. However, canned beans reduced in sodium contained an average sodium content of 153 mg/serving. Canned vegetables had a mean sodium content of 360 mg/serving. However, canned vegetables that were lower in sodium had a mean sodium content of 70 mg/serving. The mean sodium content per serving for the canned tomatoes were 250 mg/serving. Canned products contain sodium primarily for flavoring purposes, and generally contain a 1-2% sodium solution (Hutton, 2002). Lower sodium canned products offer opportunities for decreased sodium consumption among consumers, although consumer acceptance of lower sodium canned products requires further research. Within the snack foods category, food products had a mean sodium content ranging between 59 mg – 343 mg/serving (Figure 3.1) which is a wide range. Nuts and trail mix both had a mean sodium content meeting a low sodium claim, and pretzels and popcorn categories contained higher sodium quantities. Saltiness is the major sensory characteristic in snack foods, and allows for other flavor components to be distributed throughout the finished product (Matz, 1993).

3.5 Conclusions

With sodium and fat both being significant contributors towards the sensory properties of processed foods, a reduction of sodium in reduced and lower fat processed food systems could synergistically decrease consumer acceptance Study findings show that, with several food categories, when one key ingredient that drives liking, such as fat, is reduced, the other key ingredient that also drives liking, such as sodium, is increased. Potential reasons for this inverse relationship should be examined further. This relationship between sodium and fat content in some processed food products may stem from food manufacturers' desire to maintain palatability of the product via compensating one ingredient by another. With taste playing a major role in purchasing of processed food products, sensory acceptability of foods with inverse levels of sodium and fat content can be examined in order to identify drivers of liking within these levels. In order to identify the optimum amount of sodium reduction in lower fat food products, threshold testing for sodium in varying fat levels is an area for additional research. Although the inverse relationship that occurs between sodium and fat in several processed food categories contradicts recommended nutrition therapies for hypertensive individuals, the study does not demonstrate that consumers are aware of this inverse relationship in processed food systems. Consumer knowledge of sodium and fat content may require further examination in order to see if there is any awareness of this inverse relationship.

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3.7 Tables and Figures

Table 3.1: Nutrition Label Information for Processed Food Categories

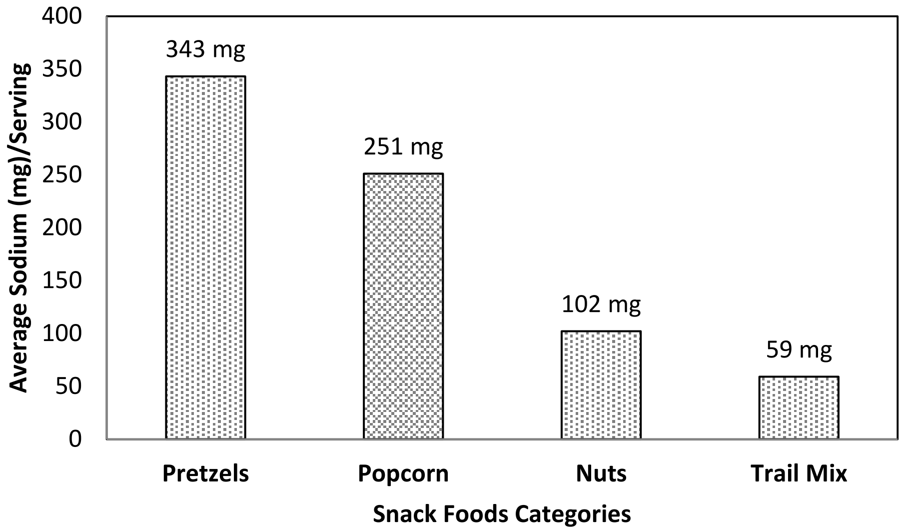
Category	# nutrition labels collected	Serving Size	# regular fat labels	# labels meeting sodium claim	# reduced/lower fat labels	# reduced/ lower fat labels meeting sodium claim
Salad Dressings	350	30-34 grams	224	8	126	14
Snack Foods (Potato Chips)	107 (out of 397)	28 grams	78	12	29	---------
Snack Foods (Chips)	53 (out of 397)	28 grams	40	4	13	1
Snack Foods (Tortilla Chips)	40 (out of 397)	28 grams	36	32	4	-------
Snack Foods (Pretzels)	40 (out of 397)	24-31 grams	5	--------	35	2
Snack Foods (Popcorn)	11 (out of 397)	28 grams	11	2	--------	---------
Snack Foods (100 calorie pack)	26 (out of 397)	21-24 grams	20	11	6	1
Snack Foods (Nuts)	45 (out of 397)	28 grams	45	27	-------	---------
Snack Foods (Trail Mix)	46 (out of 397)	27-44 grams	44	37	2	2
Snack Foods (Beef Jerky)	12 (out of 397)	28 grams	7	-------	5	-------
Snack Foods (Rice Snacks)	23 (out of 397)	9-30 grams	8	4	15	9
Deli Meats	141	28 (1 slice) – 64 (3 slices) grams	43	-------	98	8
Soups	494	120 (0.5 cup) – 245 (1 coup) grams	123	22	371	183
Frozen Dinners	458	142-454 grams	218	---------	240	--------
Canned Beans	136	112-130 grams	------	----------	136	27
Cereal	152	21-58 grams	------	---------	152	63
Breads (White)	43 (out of 255)	26-57 grams	--------	---------	43	2
Breads (Wheat)	127 (out of 255)	26-53 grams	--------	---------	127	28
Breads (Bagels)	12 (out of 255)	46-95 grams	1	---------	11	--------
Breads (Hotdog and Hamburger Buns)	45 (out of 255)	35-80 grams	-------	---------	45	1
Breads (English Muffins)	9 (out of 255)	57-61 grams	-------	---------	9	1
Canned Vegetables	131	110-165 grams	-------	--------	131	23
Tomato Products (Canned Tomatoes)	96 (out of 193)	22-128 grams	-------	---------	96	20
Tomato Products (Pasta Sauce)	97 (out of 193)	120-129 grams	25	-------	72	---------

Table 3.2: Average Sodium Content for Regular and Lower Fat Grocery Categories[†]

Grocery Category	Flavor/Brand	Average Sodium (mg) Regular Fat Labels	Average Sodium (mg) Lower Fat Labels
Salad Dressings	Italian[††]	344[a]	367[a]
	Ranch[†††]	267[a]	331[b]
	French[††††]	250[a]	274[a]
Deli Meats	A[†††††]	326[a]	511[b]
	B[††††††]	618[a]	434[a]
Soups (All)		857[a]	803[b]
Frozen Dinners (All)		887[a]	585[b]
Frozen Dinners	A[†††††††]	632[a]	580[a]
	B[††††††††]	750[a]	618[b]

[†]Means showing a common letter are not significantly different ($\alpha = 0.05$)
[††]Salad Dressings, Italian Flavor: Regular labels = 29, Reduced Fat labels = 15.
[†††]Salad Dressings, Ranch Flavor: Regular labels = 29, Reduced Fat labels = 14.
[††††]Salad Dressings, French Flavor: Regular labels = 8, Reduced Fat labels = 5.
[†††††]Deli Meats, Brand A: Regular labels = 19, Reduced Fat labels = 23.
[††††††]Deli Meats, Brand B: Regular labels = 19, Reduced Fat labels = 14.
[†††††††]Frozen Dinners, Brand A: Regular labels = 18, Reduced Fat labels = 16.
[††††††††]Frozen Dinners, Brand B: Regular labels = 31, Reduced Fat labels = 40.

Figure 3.1: Average Sodium Content for Snack Foods Categories



Chapter 4: Sodium and Fat Nutrient Label Claims Knowledge of Consumers and Health and Food Professionals

4.1 Abstract

Processed food choices account for over 77% of the average American's daily sodium consumption, totaling more than 3400 mg, which is more than the recommended daily intake of 2300 mg. As consumers continue to demand healthier foods, comprehension of nutrition information displayed on food products is critical, specifically sodium content. With the prevalence of diseases linked to increased sodium and fat intake, including hypertension, comprehension of nutrition information displayed on food products is critical. Due to the role that health and food professionals have in the food industry, comprehension of nutrition information is also of importance for these occupations. The objective of this study was to measure the knowledge base of consumers and health and food professionals on the nutrition facts label, specifically sodium and fat nutrient claims were measured. A thirty-five question survey was conducted online through SurveyMonkey®. The survey was targeted towards general consumers and health and food professionals. Variables measured included nutrient claim labeling, nutrient consumption, family history and concern of disease states, demographic information. A total of 976 surveys were completed. The completed surveys included 453 general consumers, 160 food scientists, 84 foodservice professionals, 230 nutrition professionals, and 49 medical professionals. Participants recruited through professional organizations and social media outlets. The survey was analyzed by one-way analysis of variance ($p \leq 0.05$). There was a statistically significant difference in comprehension of nutrient content claims across the groups. Nutrition professionals had the highest percentage of correct responses (71%). Medical professionals had the lowest percentage of correct responses (36%). There was a statistically significant difference in comprehension of ‘free,’ ‘low,’ and ‘reduced’ claims. Increased comprehension of the nutrition facts label and nutrient content claims may be increased through nutrition education. Further research studies could include effective methods of nutrition education and consumer acceptance of food products with specified nutrient content claims for sodium and fat.

Key Words: nutrition labels, nutrition survey, nutrition knowledge, sodium, fat

4.2 Introduction

Hypertension affects nearly 78 million adults in the US, and more than 90% of US adults will develop hypertension in their lifetime (Vasan, 2002; Go and others, 2013). At risk groups include individuals who have hypertension, adults 51 years of age and older, and African Americans. Studies have examined that overweight and obesity and increased dietary sodium consumption are key factors in the incidence and prevalence of hypertension (Loria and others, 2001; Wofford, 2008; Bayer and others, 2012).Over 70% of hypertensive individuals are either overweight or obese (Jeffery and others, 1983; Wofford, 2008).

The average estimated daily consumption of dietary sodium is over 3400 mg for all Americans ages 2 years and older (NHANES, 2010). This intake is far more than the recommended daily consumption of 2300 mg set by the 2010 Dietary Guidelines for Americans (USDA, 2010). Processed foods consist of 80% of the food supply in the United States (US), and account for over 77% of the average American's daily sodium consumption (Levings and others, 2012; CDC, 2010).

There is limited research on comprehension of nutrient content claims on processed foods pertaining to sodium and fat. The FDA 2008 Health and Diet Survey reported that 54% of respondents often read a food label when purchasing a processed food product for the first time. Additionally, 66% reported using the label to assess quantity of calories, salt, fat, or vitamins (FDA, 2008). Comprehension of nutrient content claims may assist in consumers choosing food products lower in sodium and fat and should be assessed.

The Nutrition Facts Label aims to improve the American diet by providing consumers information on portion sizes, calories, and nutrient values (Taylor and others, 2008). Developed from the 1990 Nutrition Labeling and Education Act (NLEA), the Nutrition Facts Label provides the framework for nutrition label claims, including nutrient content claims. Nutrient content claims indicate the level of a nutrient in the product as defined by the Food and Drug Administration (FDA, 2013). Nutrient content claims were created to establish consistent terms and definitions for nutrient content in food products. The FDA Food Label and Package Survey indicated that 54 of 57 food product groups sampled contain nutrient content claims (Brandt and others, 2010).

Because of their role in communicating nutrition information to consumers and in the development of food products, it is important to assess the nutrition knowledge of health and food professionals. Physicians are not only seen as medical experts, but also as the primary source of dietary advice related to health (Kushner, 1985). However, nutrition has been underrepresented in the curriculum at many medical schools (Adams and others, 2010). A survey examining nursing school curriculums found that only 50% of faculty felt the nutrition content included in the program was adequate (DiMaria-Ghalili and others, 2014).

Food scientists develop new food products and improve existing food products. Many of these food products have nutrient content standards. Food scientists are required to take one course in nutrition according to curriculum standards (IFT, 2011). Limited research has assessed the nutrition knowledge of food scientists.

Foodservice professionals, including chefs and other hospitality personnel, may be subject to corporate, state, or federal mandates to improve the nutritional content of prepared foods. However, employees in the foodservice sector may have no more nutrition knowledge than the average American (Regan and others, 1991). In a survey which evaluated for food science and nutrition knowledge, chefs had difficulty with nutrition related questions (Reichler et. al, 1998). Nutrition professionals, such as Registered Dietitians and nutritionists, take various nutrition courses according to curriculum standards (ACEND, 2013).

The overall goal of this study was to survey consumer knowledge of sodium and fat content in processed foods so as to assess comprehension of nutrient content claims across different groups of professionals and the general public. In order to accomplish the overall goal, an online survey was developed. The specific objectives of the survey were to: 1) compare knowledge base of consumers for nutrient content claims and recommended dietary intake, specifically for sodium, fat, and sugar, 2) compare knowledge base of targeted health and food professionals for nutrient content claims and recommended dietary intake, specifically for sodium, fat, and sugar, 3) compare the concern of specified health conditions and family history of specified health conditions, 4) compare nutrient consumption and purchasing intent of sodium and fat to knowledge of nutrient content claims, and 5) compare body mass index (BMI) and knowledge of nutrient content claims.

We hypothesized that consumers are not knowledgeable (less than 50% correct response rate) on nutrient content claims pertaining to sodium and fat. We hypothesized that, based on current requirements for nutrition education, medical professionals, foodservice professionals, and food scientists are not knowledgeable on nutrient content claims pertaining to sodium and fat. We hypothesized that the level of concern of specified health conditions would not differentiate between family history of specified health conditions. We hypothesized that groups which had a high level of concern regarding nutrient consumption and purchasing of sodium and fat would have more knowledge of nutrient content claims. We hypothesized that body mass index would not be an indicator of increased knowledge of nutrient content claims.

4.3 Materials and Methods

4.3.1 Survey Design

The survey consisted of 35 questions (Table 4.1). The survey was designed by 2 food and nutrition experts. Thirteen questions pertained to knowledge of nutrient content claims for three nutrients: sodium, fat, and sugar. Six questions focused on dietary consumption of sodium, fat, sugar and specific food products. Seven questions focused on concern with regards to sodium, fat, and sugar intake and related health conditions. Nine questions highlighted demographic information. The survey was conducted online via Survey Monkey® (www.surveymonkey.com). This research study was reviewed and approved by the University of Illinois at Urbana Champaign (UIUC) Institutional Review Board. Participants were presented with an online consent form, and agreed to participate in the online survey by selecting a button before proceeding to the survey.

4.3.2 Measures

Nutrient Knowledge. Survey participants were asked fifteen questions pertaining to nutrient content claims for sodium, fat, and sugar. Nutrient content claims included in the survey for sodium were "free," "low," "reduced," "lite/light," and "lightly salted." Two questions were presented for the "reduced" sodium content claim. Nutrient content claims presented for fat were "free," "low," and "reduced." Two questions were presented for the "free" fat content claim. Nutrient content claims examined for sugar were "no added sugar," "free," and "reduced." For "reduced" sodium and fat "free" claims, two questions were presented in order to assess comprehension of a nutrient content claim when presented in a mathematical context versus as an open-ended question. Two questions were presented on the recommended daily intake of sodium and fat.

Dietary Consumption. Four questions asked the knowledge base of recommended dietary intake. Three questions were presented on daily consumption of sodium, fat, and sugar. One question asked for regular (at least once every two weeks) consumption of common food products (cereals, soups, deli meats, canned meats, breads, canned vegetables, frozen vegetables, canned beans, salad dressings, frozen dinners, tomato-based products, snack foods).

Concern of Nutrient Consumption and Health Conditions. Seven questions were presented for concern of nutrient consumption and health conditions. Two questions asked for concern of sodium and fat content in daily food consumption. Two questions asked for the importance of sodium and fat content in purchasing decisions. Two questions investigated perception of the most healthy and unhealthy food products based on nutrient content information provided for sodium, fat, and sugar content. Concern of specified health conditions (hypertension, diabetes, heart disease, high cholesterol, gastrointestinal problems, obesity, and cancer) was questioned among survey participants.

Demographic Measures. Nine demographic measures, age, gender, ethnic group, household income before taxes, education, occupation, and family history of specific health conditions (hypertension, diabetes, heart disease, high cholesterol, gastrointestinal problems, obesity, cancer), were included in the survey. Self-reported height and weight were additionally collected.

4.3.3 Subjects

Consumers were defined as any individual over the age of 18 with any occupation not specifically targeted in the survey. Health and food related professionals targeted for the survey included medical professionals, nutrition professionals, food scientists, and food service professionals. Medical professionals included Medical Doctors, Registered Nurses, and other nursing professionals. Nutrition professionals included Registered Dietitians and other nutrition professionals. Food service professionals included chefs, cooks, and other hospitality professionals. Participants were recruited through professional organizations and via online social and professional outlets including Facebook, LinkedIn, and Twitter. A total of 1151 surveys were initiated. There were 561 surveys initiated for general consumers, 50 for medical professionals, 307 for nutrition professionals, 186 for food scientists, and 132 for food service professionals. A total of 976 surveys were completed. There were 453 completed surveys for general consumers, 160 for food scientists, 84 for foodservice professionals, 230 for nutrition professionals, and 49 for medical professionals.

4.3.4 Statistical Analysis

Survey data were transported from SurveyMonkey® and analyzed using XLSTAT (Version 2013: Addinsoft USA, New York, NY, U.S.A.). Analysis of variance (ANOVA) was conducted, and the calculated probabilities obtained from the analysis were compared to the significance level of 0.05. Tukey's honest significant difference (HSD) was conducted when a significant difference was determined by ANOVA.

4.4 Results and Discussion

4.4.1 Knowledge of Nutrient Content Claims and Recommended Dietary Intake for Consumers and Health and Food Professionals

There was a statistically significant difference in the percentage of correct answers across all occupations ($p < 0.05$) for questions regarding nutrient content claims and recommended dietary intake (Figure 4.1). Medical professionals had the lowest mean percentage of correct responses (36%), followed by general consumers (44%), foodservice professionals (53%), food scientists (64%), and nutrition professionals (71%). The percentage of correct answers by nutrition professionals was significantly higher than those of medical professionals and consumers ($p<0.05$).

Survey results indicated that consumers are not knowledgeable on nutrition labels pertaining to sodium and fat content in processed foods. Medical professionals demonstrate significant lack of knowledge on nutrient content claims. Nutrition education for physicians has been recommended, in order for the physicians to accurately advise consumers on the benefits of dietary sodium reduction (Dickinson, 2007). Prior surveys showed that physicians agree on the importance of nutrition in their medical practice, but do not feel adequately prepared to provide nutrition counseling to their patients (Kushner, 1995). The nutrition education of physicians and other health care providers could impact a target group, middle-age consumers who are not yet hypertensive but are at high risk throughout the remainder of their life span (Lichtenstein and others, 2006). Since 90% of individuals will have hypertension within their lifetime, consumers may be unaware that excessive sodium consumption is a concern for everyone and not solely for hypertensive individuals (Howlett and others, 2012). Providing physicians with nutrition education could potentially assist with delaying or preventing hypertension with this particular demographic.

When nutrient content claims were compared across all participants, there was a statistically significant ($p < 0.05$) difference between the 'reduced,' 'free,' and 'low' nutrient content claims across all occupations (Figure 4.2). 'Reduced' claims had the highest mean percentage of correct responses, and 'low' claims had the lowest mean percentage of correct responses. There was no significant ($p < 0.05$) difference between ‘free’ and ‘reduced’ nutrient content claims. There was a significant difference between the ‘low’ and ‘free’ and ‘reduced’ nutrient content claims.

Survey analysis indicated there is a better understanding of ‘reduced’ and ‘free’ claims versus ‘low’ claims across all nutrient categories examined. Comprehension of nutrient content claims was reported to be impacted by the context in which the question was presented. Survey respondents demonstrated a better understanding of nutrient content claims when presented as a in a mathematical context. However, the type of math problem presented also impacts comprehension. When the ‘reduced sodium’ claim was presented as a math problem, all survey respondents had a higher percentage of correct responses than the ‘reduced sodium’ claim that was presented as an open-ended question. When the ‘fat free’ claim was presented in a mathematical context, all survey respondents had a lower percentage of correct responses than the ‘fat free’ claim that was not presented as an open-ended question.

4.4.2 Comparison of Concern of Health Conditions and Nutrient Consumption

Results for health conditions of concern and health conditions in family history are reported in Figure 4.3. Cancer was selected as the leading disease concern (54%), followed by heart disease (53%) and obesity (52%). Hypertension was the sixth ranking disease of concern (43%). However, hypertension ranked as the leading disease state in the family history (56%).

4.4.3 Comparison of Nutrient Consumption and Purchasing Intent of Sodium and Fat and Knowledge of Nutrient Content Claims

When nutrient content claim questions for fat, sugar, and sodium were separated by level of concern of daily dietary sodium intake, there was a significant difference between the percentage of correct responses from all levels of concern about daily dietary sodium intake (Table 4.2).Those who were not concerned about daily dietary sodium intake had a significantly greater percentage of correct responses compared to those that were very concerned or somewhat concerned. Additionally, there was a significant difference between the percentages of correct responses from those who were somewhat concerned and not concerned about daily dietary fat intake compared to those that were very concerned (Table 4.2). When nutrient content claim questions for fat, sugar, and sodium were separated by level of importance of sodium content when purchasing a food product, there was a significant difference between the percentage of correct responses from those who thought sodium content in food products were very or somewhat important in purchasing compared to those who thought it was not important (Table 4.2). Furthermore, there was a significant different across all levels for importance of fat content when purchasing a food product (Table 4.2).

4.4.4 Comparison of Body Mass Index of Sodium and Knowledge of Nutrient Content Claims

When knowledge of nutrient content claim questions for sodium, fat, and sugar were separated by BMI, those individuals who reported themselves as underweight(<18.5) had a significantly higher percentage of correct responses than the other BMI categories (Figure 4.4). There was no difference between the percentage of correct responses between normal (18.5-24.9) and overweight (25.0-29.9) categories, and there was no difference between the percentage of correct responses between overweight and obese categories (>30).

4.6 Conclusions

Survey results indicate that there is room for increased comprehension of nutrient content claims and recommended dietary intake by consumers and health and food professionals. With the increased incidence and prevalence of hypertensive individuals, comprehension of nutrition information displayed on food products is critical. Additionally, comprehension of nutrient content claims may highlight the correlation between sodium consumption and hypertension for consumers.

Study findings are limited to the label claims evaluated and are not extended to the understanding of the nutrition facts label. Further studies can be designed to determine the relationship between nutrition education and understanding of label claims and nutritional facts label. Further research could examine if nutrition education would increase comprehension of the nutrition facts label. Comparisons of nutrition education programs and their effectiveness could also be determined. Though nutrition education interventions may increase consumer knowledge of the nutrition facts label, consumer acceptance may remain unchanged regardless of increased comprehension of claims. Consumer acceptance of food products containing both sodium and fat nutrient content claims would need to be determined in the context of actual food consumption

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4.8 Tables and Figures

Table 4.1: Nutrition Facts Label Survey

Question Category	**Selection of Responses** (* indicates correct response to question)
Nutrient Knowledge	
1. A food product that is labeled as "no added sugar" or "no sugar added":	• Has all the sugar removed from the product during processing • *Has no sugars added during processing or packaging • Has some sugar removed from the product during processing • Do not know
2. A food product that is labeled as "low sodium":	• Has 35 milligrams or less of sodium per serving • *Has 140 milligrams or less of sodium per serving • Has at least 25% less sodium per serving than the regular food product • Do not know
3. A food product that is labeled as "low fat":	• Has less than 0.5 grams of fat per serving • *Has 3 grams or less of fat per serving • Has at least 25% less fat per serving than the regular food product • Do not know
4. A food product that is labeled as "reduced sugar":	• *Has at least 25% less sugar per serving than the regular food product • Has at least 30% less sugar per serving than the regular food product • Has at least 50% less sugar per serving than the regular food product • Do not know
5. A food product that is labeled as "reduced sodium" or "less sodium":	• *Has at least 25% less sodium per serving than the regular food product • Has at least 30% less sodium per serving than the regular food product • Has at least 50% less sodium per serving than the regular food product • Do not know
6. A food product that is labeled as "reduced fat" or "less fat":	• *Has at least 25% less fat per serving than the regular food product • Has at least 30% less fat per serving than the regular food product • Has at least 50% less fat per serving than the regular food product • Do not know
7. A food product that is labeled as "sugar free":	• Has no sugar content in the food product • Has at least 25% less sugar per serving than the regular food product • *Has less than 0.5 grams of sugar per serving • Do not know
8. A food product that is labeled as "sodium free":	• Has no sodium content in the food product • *Has less than 5 milligrams of sodium per serving • Has 35 milligrams or less of sodium per serving • Do not know
9. A food product that is labeled as "fat free":	• Has no fat content in the food product • *Has less than 0.5 grams of fat per serving • Has 3 grams or less of fat per serving • Do not know
10. A food product that is labeled as "light in sodium" or "lite in sodium":	• Has at least 25% less sodium per serving than the regular food product • *Has at least 50% less sodium per serving than the regular food product • Has at least 75% less sodium per serving than the regular food product • Do not know

Table 4.1 (continued)

Question Category	Selection of Responses (* indicates correct response to question)
11. A food product that is labeled as "lightly salted" :	• Has at least 25% less sodium per serving than is normally added to the regular food product • *Has at least 50% less sodium per serving than is normally added to the regular food product • Has at least 75% less sodium per serving than is normally added to the regular food product • Do not know
12. According to the nutrition facts label, a food product contains less than 0.5 grams of fat per serving. The food product contains a total of 50 servings. From the information on the label, the food product could have the claim of:	• Reduced fat • Low fat • *Fat free • Do not know
13. A food product label contains 1000 milligrams of sodium per serving. The new, updated label shows a content of 750 milligrams of sodium per serving. According to the updated label, the food product could have the claim of:	• *Less or reduced sodium • Low sodium • Sodium free • Do not know
Dietary Consumption	
14. What is the recommended daily intake of sodium based on a 2,000 calorie diet for the average American?	• 4800 milligrams of sodium daily, equivalent to roughly 2 teaspoons salt • 2300 milligrams of sodium daily, equivalent to roughly 1 teaspoon salt • 1500 milligrams of sodium daily, equivalent to roughly ½ teaspoon salt • Do not know
15. What is the recommended daily intake of fat based on a 2,000 calorie diet for the average American?	• 100 grams of fat daily, or 45% of total daily calories • 65 grams of fat daily, or roughly 30% of total daily calories • 20 grams of fat daily, or roughly 10% of total daily calories • Do not know
16. How much sodium do you think you consume in your daily diet?	• 1500 milligrams daily, equivalent to roughly ½ teaspoon salt • 2300 milligrams daily, equivalent to roughly 1 teaspoon salt • 4800 milligrams daily, equivalent to roughly 2 teaspoons salt • More than 4800 milligrams daily
17. How much sugar and/or carbohydrates do you think you consume in your daily diet?	• 200 grams daily, or roughly 40% of total daily calories • 250 grams daily, or roughly 50% of total daily calories • 300 grams daily, or roughly 60% of total daily calories • More than 300 grams daily • Do not know
18. How much fat do you think you consume in your daily diet?	• 20 grams of fat daily, or roughly 10% of total daily calories • 65 grams of fat daily, or roughly 30% of total daily calories • 100 grams of fat daily, or 45% of total daily calories • More than 100 grams of fat daily • Do not know

Table 4.1 (continued)

Question Category	Selection of Responses (* indicates correct response to question)
19. Select all the products you consume on a regular basis (at least once every two weeks)	• cereal • soup • lunch and deli meats (ham, turkey, roast beef, corned beef, bologna) • canned meats/meat products (canned chicken, spam, canned sausage) • bread • canned vegetables • frozen vegetables • canned beans • salad dressing • low fat frozen dinners (Lean Cuisine, Healthy Choice) • tomato-based products (canned tomatoes, spaghetti/ pasta sauce) • snack foods (potato chips, pretzels, popcorn, trail mix, granola bars, 100 calorie snack packs)
Concern of Nutrient Consumption and Health Conditions	
20. How concerned are you about the amount of sodium that is in your daily food intake?	• Very concerned • Somewhat concerned • Not concerned
21. How concerned are you about the amount of fat that is in your daily food intake?	• Very concerned • Somewhat concerned • Not concerned
22. How important is sodium content to you when purchasing a food product?	• Very concerned • Somewhat concerned • Not concerned
23. How important is fat content to you when purchasing a food product?	• Very concerned • Somewhat concerned • Not concerned
24. Which of the following food products do you think is the most healthy?	• A food product that is reduced in sodium content • A food product that is reduced in fat content • A food product that is reduced in sugar content
25. Which of the following food products do you think/perceive is unhealthier?	• A food product that is high in sodium content • A food product that is high in fat content • A food product that is high in sugar content
26. Which of the following health conditions are you most concerned of? (check all that apply)	• High blood pressure/Hypertension • Diabetes • Heart disease • High cholesterol • Gastrointestinal problems • Obesity • Cancer

Table 4.1 (continued)

Question Category	**Selection of Responses** (* indicates correct response to question)
Demographic Measures	
27. Which of the following health conditions are in your family history? (check all that apply)	• High blood pressure/Hypertension • Diabetes • Heart disease • High cholesterol • Gastrointestinal problems • Obesity • Cancer
28. What is your current age?	• 18 to 29 • 30 to 39 • 40 to 49 • 50 to 59 • 60 to 69 • 70 or older
29. Please select your gender.	• Male • Female
30. Which of the following best describes your race?	• White or Caucasian • Black or African American • Asian or Pacific Islander • Native American • Hispanic • More than one race • Some other race • Prefer not to answer
31. Please select the option that best describes your annual household income before any taxes.	• Less than $20,000 • $20,000 to less than $30,000 • $30,000 to less than $40,000 • $40,000 to less than $50,000 • $50,000 to less than $70,000 • $70,000 to less than $100,000 • $100,000 or more • Not sure • Prefer not to answer

Table 4.1 (continued)

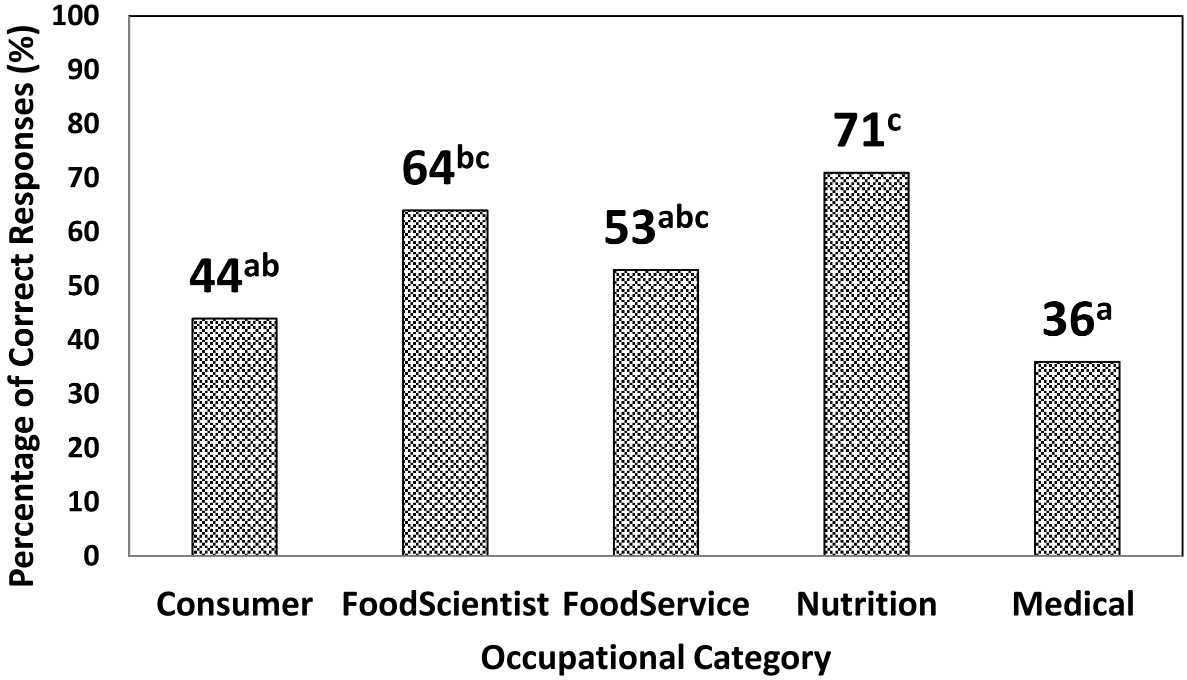
Question Category	Selection of Responses (* indicates correct response to question)
32. Please select your highest level of education	• High school diploma/GED • Associate's degree • Other type of certificate • Bachelor's degree • Master's degree • Other post graduate degree • Ph.D. • J.D. • M.D. • Other doctoral degree
33. Please select your occupation	• Medical Doctor • Registered Nurse • Licensed Practical Nurse • Registered Dietitian • Nutritionist • Other health professional • Food scientist • Chef • Other food industry professional • Other occupation • No occupation (ex. student, retired)
34. Please select the range your current height is in:	• 4 ft. 5 in. – 5 ft. 0 in. • 5 ft. 1 in. – 5 ft. 6 in. • 5 ft. 7 in. – 6 ft. 0 in. • 6 ft. 1 in. – 6 ft. 6 in. • 6 ft. 7 in. – 7 ft. 0 in. • Prefer not to answer
35. Please select the range your current weight is in:	• 95 lbs. - 110 lbs. (43 kg – 50 kg) • 111 lbs. – 125 lbs. (50.5 kg – 56 kg) • 126 lbs. – 140 lbs. (57 kg – 63 kg) • 141 lbs. – 155 lbs. (64 kg – 70 kg) • 156 lbs. – 170 lbs. (71 kg – 77 kg) • 171 lbs. – 185 lbs. (77.5 kg – 84 kg) • 186 lbs. – 200 lbs. (84.5 kg – 90 kg) • 201 lbs. – 225 lbs. (91 kg – 102 kg) • 226 lbs. – 250 lbs. (102.5 kg – 113 kg) • 251 lbs. – 275 lbs. (114 kg – 125 kg) • 276 lbs. – 300 lbs. (125.5 kg – 136 kg) • More than 300 lbs. (more than 136 kg) • Prefer not to answer

Table 4.2: Comparison of Nutrient Content Claim Questions for Fat, Sugar, and Sodium Separated by 1) Level of Concern of Daily Dietary Intake and 2) Level of Importance When Purchasing a Food Product[†]

Level of Concern for Daily Dietary Intake		
Very Concerned (Sodium)	Somewhat Concerned (Sodium)	Not Concerned (Sodium)
54[c]	55[b]	58[a]
Very Concerned (Fat)	Somewhat Concerned (Fat)	Not Concerned (Fat)
52[b]	56[a]	58[a]
Level of Importance of Nutrient Content when Purchasing a Food Product		
Very Concerned (Sodium)	Somewhat Concerned (Sodium)	Not Concerned (Sodium)
57[a]	56[a]	52[b]
Very Concerned (Fat)	Somewhat Concerned (Fat)	Not Concerned (Fat)
54[b]	57[a]	52[c]

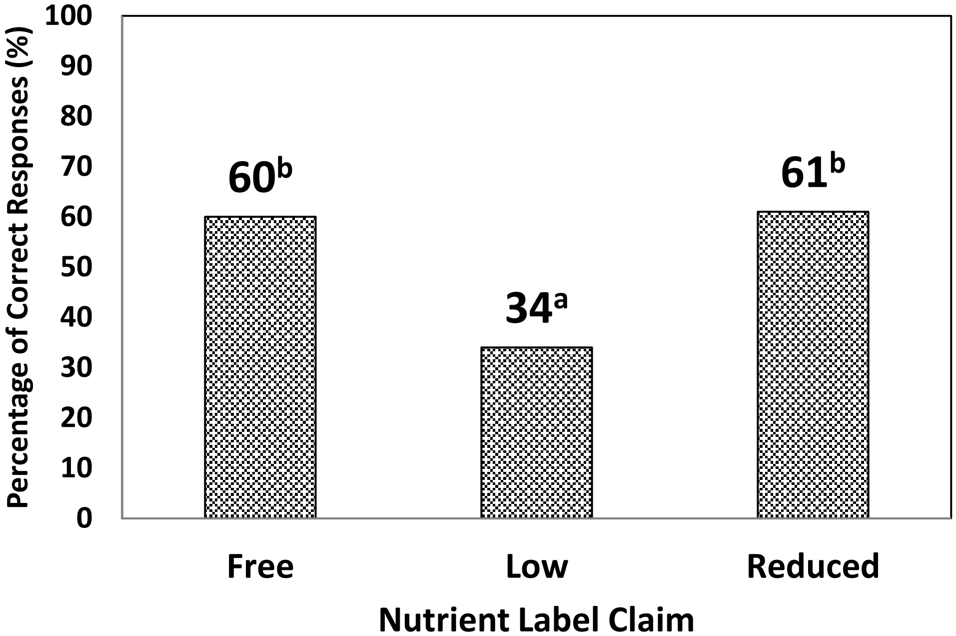
Means showing a common letter are not significantly different ($\alpha = 0.05$).
[†]Indicates percentage of correct responses

Figure 4.1: Comparison of Nutrient Content Claim Questions for Fat, Sugar, and Sodium Separated by Occupational Category



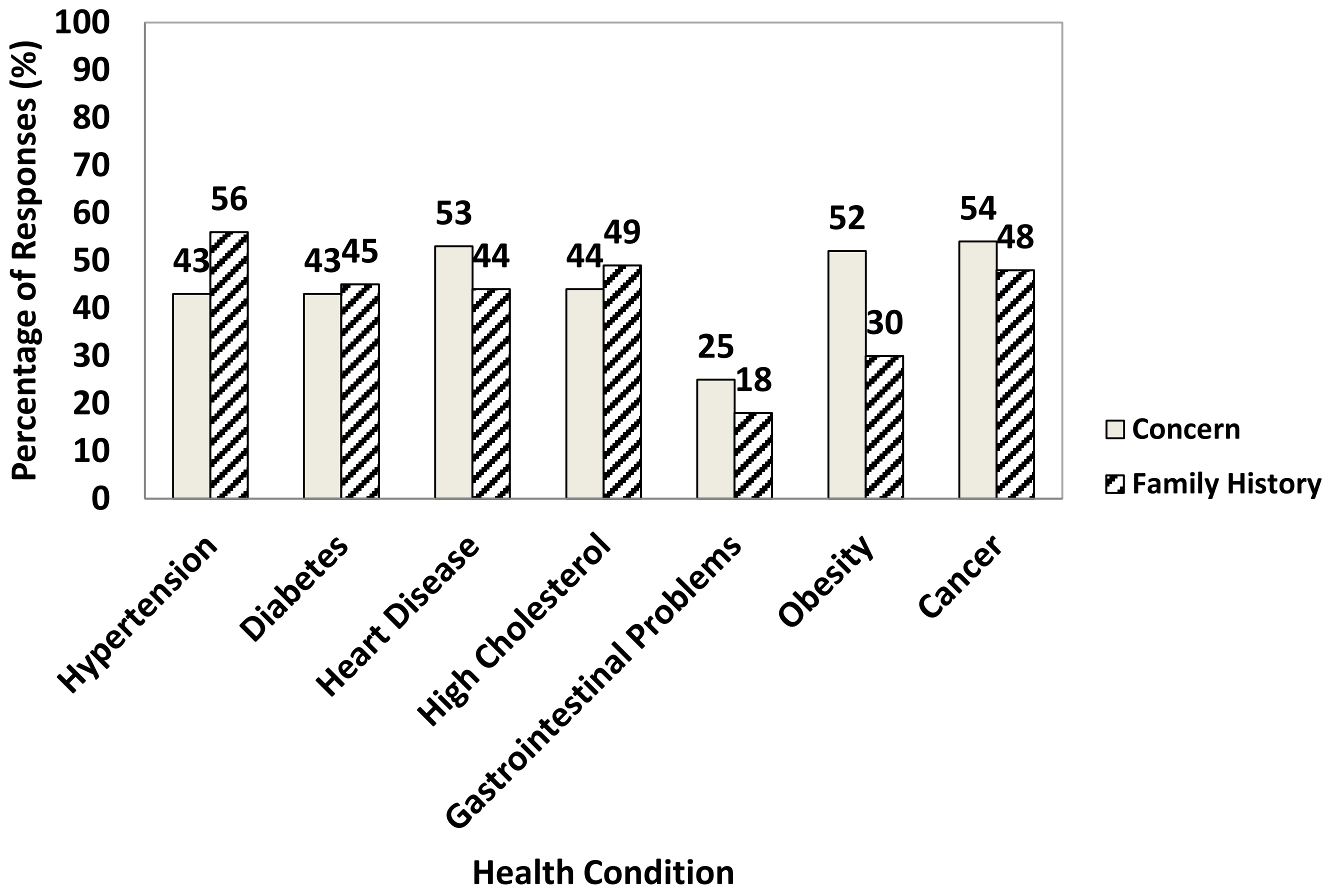
Means showing a common letter are not significantly different (α = 0.05).

Figure 4.2: Comparison of Nutrient Content Claim Questions for Fat, Sugar and Sodium Separated by Type of Claim



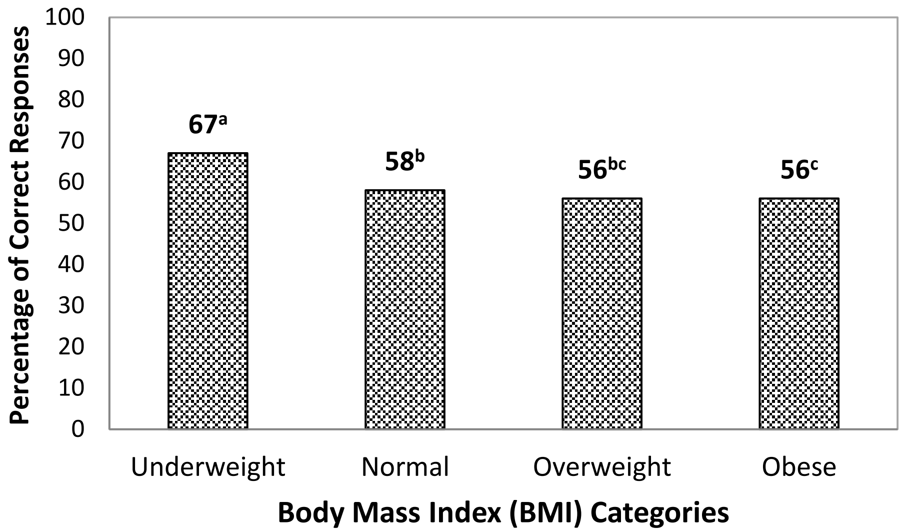
Means showing a common letter are not significantly different (α = 0.05)..

Figure 4.3: Comparison of Concern vs. Family History of Health Conditions (Hypertension, Diabetes, Heart Disease, High Cholesterol, Gastrointestinal Problems, Obesity, Cancer)



Means showing a common letter are not significantly different (α = 0.05).

Figure 4.4: Comparison of Nutrient Content Claim Questions for Fat, Sugar, and Sodium Separated by Reported Measure of Body Mass Index (BMI)



Means showing a common letter are not significantly different (α = 0.05).

Chapter 5: Drivers of Liking in a Model Retorted Creamy Tomato Soup System with Varying Levels of Sodium, Fat, and Herbs

5.1 Abstract

Targeting sodium reduction in processed food sources has been projected to decrease hypertension (CDC, 2012). Over 77% of sodium consumption stems from processed foods, and the majority of hypertensive adults are also overweight or obese. Therefore, methods for both sodium and fat reduction in processed food sources can be examined. The study objective was to determine the drivers of liking when sodium, fat, and herb levels are varied in a model retorted soup system. A creamy tomato soup system was developed containing four fat levels (free, low, reduced, regular), three sodium levels (low, reduced, regular), and two herb levels (with, without). Ninety-six consumers rated the soups for overall liking on a 9-point hedonic scale. A descriptive analysis panel comprised of 10 trained panelists profiled the sensory attributes among the soups. Higher sodium level was found to be a driver of liking when fat content was reduced. Soups were significantly different in saltiness and tomato aroma-by-mouth, based on varying fat and salt levels. Herb content increased overall liking of lower sodium and fat and impacted attribute characterization of soups. Future steps would include approaches to increase overall liking of lower fat and sodium soups. Formulation modifications which would result in decreasing intensities of attributes that characterize lower fat and sodium soups, such that the drivers of disliking are decreased, will aid in developing soups with higher consumer acceptance.

Practical Applications:

With the majority of hypertensive individuals requiring reductions of both sodium and fat in food systems, food products lower in fat and sodium while maintaining sensory properties for consumer acceptance are needed. These results indicate that identifying drivers of liking when sodium and fat levels are reduced in processed food systems can assist in product reformulation to increase overall liking. Additionally, understanding the impact of herbs in consumer acceptance of lower sodium and fat food products will also contribute to further advances in product development.

Keywords: sodium, fat, soup, herb, consumer testing, descriptive analysis

5.2 Introduction

Approximately nine out of ten people in the United States consume more sodium than recommended (CDC, 2012). The recommended intake for dietary sodium is less than 2,300 mg daily. However, 88% of individuals consume more than the recommended amount (CDC, 2011). In addition, at-risk groups, such as individuals with hypertension, middle aged adults, and African Americans, are recommended to consume less than 1500 mg daily. From these at-risk groups, 99% of individuals consume more than the recommended amount (CDC, 2011). One in three adults in the United States has hypertension (Go and others 2013). With over 70% of hypertensive adults being either overweight or obese, both sodium and fat are contributing factors towards hypertension (Whelton and others 2002).

Sodium has several roles within a processed food system, including the enhancement of the taste and flavor of other ingredients (Durack and others 2008; Hutton, 2002). Processed food choices account for over 77% of the average American's daily sodium consumption (CDC, 2010; Mattes, 1991). The Institute of Medicine (IOM) has recommended strategies for sodium reduction, including mandatory reductions in sodium in processed and restaurant foods with interim voluntary reductions from food manufacturers (IOM, 2010).

Forty-four percent of sodium consumed comes from 10 food categories including soups (CDC, 2012). A reduction of 25% in sodium content across the top 10 food category contributors to sodium consumption could result in an 11% reduction (approximately 360mg) in total daily mean sodium consumption in the United States (CDC, 2012; Bibbins-Domingo, 2010). Though soup is a major processed food category containing high sodium content, few studies have investigated the impact of sodium reduction on the sensory characteristics of soups. Limited research, if any, has been conducted on the sensory impacts of varying sodium and fat levels in soups.

The overall goal of this study was to identify drivers of liking when sodium, fat, and herb levels are varied in a model processed soup system. The specific objectives were to 1) compare overall liking, 2) determine sensory attributes, and 3) identify the drivers of liking of a model processed soup system with varying sodium, fat, and herb levels. We hypothesized that the increase in sodium when fat is decreased, and vice versa, result in a compensatory effect, in which decreased level of one ingredient does not significantly lower consumer acceptance as a result of the increase in the other. We further hypothesized that herb levels can contribute to an increase in overall liking in reduced fat and sodium systems.

5.3 Materials and Methods

5.3.1 Sample Information

A retorted creamy tomato soup was selected as the model system. A creamy tomato soup system provides a medium in which fat, sodium, and herb levels could be easily modified. Twenty-four model retorted creamy tomato soups were prepared with 4 levels of fat (regular, reduced, low, free), 3 levels of sodium (regular, reduced, low), and 2 levels of herbs (with, without). The nutrient levels for fat and sodium content in the soups (Table 5.1.a.) were based on the US Food and Drug Administration (FDA) nutrient content claims guide (FDA, 2013).

The soup formulation consisted of the following ingredients: Hunt's no salt added tomato sauce (ConAgra Foods, Inc., Omaha, NE, U.S.A.), unsalted butter (Land O' Lakes, Inc., Arden Hills, MN, U.S.A.), fat free milk (Prairie Farms Dairy, Inc., Carlinville, IL, U.S.A.), distilled water, and salt (Morton Salt, Inc., Chicago, IL, U.S.A.). Herbs used for the soup were fresh rosemary, fresh thyme, and fresh basil (Central Illinois Produce, Urbana, IL, U.S.A.). Herb levels were based on preliminary testing (Table 5.1.b.). Ingredient composition and preparation method were based on preliminary consumer testing conducted on fresh creamy tomato soups (Appendices 5.1-5.4). Soup abbreviation and formulation information are provided in Tables 5.2 and 5.3.a-5.3.d.The soups were prepared in the University of Illinois at Urbana-Champaign pilot plant.

Soups were prepared in steam jacketed kettles, and soup cans were processed in a rotating retort (Sterilmatic, JBT FoodTech, Madera, CA, U.S.A.) to sterilize the model soup at 121.1°C. The processing time was determined based on time-temperature curves of each model soup sample using MPIII data loggers (Mesa Laboratories, Lakewood, CO, U.S.A.). Processing times for the soups were: 22 minutes for fat free and low fat, and 25 minutes for reduced and regular fat. The process scheme for the soups consisted of 9 steps: 1) melt butter (with exception of fat free soups) in steam jacketed kettle, 2) add tomato sauce and water (with exception of regular fat soups) and heat to 71°C, 3) add herbs for herb soups (placed inside cheesecloth and tied tightly), simmer in tomato sauce for 15 minutes, and remove, 4) heat milk to 71°C in a separate steam jacketed kettle, 5) add milk gradually to tomato sauce and whisk vigorously, 6) add salt to soup and whisk vigorously, 7) blend soup for 1 minute and pour in No. 10 can (leaving room for headspace), 8) place cans in retort for designated time, and 9) cool, dry, and refrigerate cans.

5.3.2 Subjects for Consumer Study

A total of 96 panelists participated in the consumer testing portion of the study. Panelists were recruited on the University of Illinois campus, and were selected based on being users and likers of creamy tomato soups, availability, and lack of food allergies and intolerance to lactose. Panelists were required to be available for four 30-minute sessions.

5.3.3 Sample Preparation for Consumer Study and Descriptive Analysis Panel

The soups were heated and served from a hot holding food unit (Vollrath 72023 Cayenne Heat 'n Serve, WI, U.S.A.). The soups were opened, blended for 1 minute, and placed into a holding pan within the holding unit. Soups were brought to a temperature range of 74°C before being served for testing in order to meet food safety guidelines (FDA, 2009). Soups were served at a temperature range between 60-74°C.

5.3.4 Sample Evaluation for Consumer Study

The panelists rated the 24 soups for overall liking on a 9-point hedonic scale (Peryam and Pilgrim, 1957). Participants evaluated 12 soups for each session. Six soup samples were presented to panelists for testing. A 5 minute break followed to minimize palate fatigue, and six additional soup samples were presented to panelists for testing.

Participants were presented with a 30-mL sample of the soup in a 60-mL capacity Styrofoam bowl (Solo Cup Company, U.S.A.). Participants were instructed to taste a teaspoon of the sample for sensory rating. Participants were instructed to follow a rinse protocol of rinsing with carbonated water (Meijer, Inc., Grand Rapids, MI, U.S.A.), warm distilled water (38-49°C), and room temperature distilled water before evaluating each sample. Two replications of the 24 soups were presented to the panelists at the end of the 4 sessions. Soup samples were assigned 3-digit randomized codes. The order of sample presentation was randomized by the Williams design, and sample randomization was done through the Compusense *five* Plus (Version 5.0: Guelph, Ontario, Canada) data acquisition program.

5.3.5 Subjects for Descriptive Analysis Study

A total of 10 panelists (4 male, 6 female, 23 to 41 years old) participated in the descriptive analysis portion of the study. Panelists were recruited on the University of Illinois campus, and were selected based on interest in creamy tomato soups, availability, and lack of food allergies and intolerance to lactose.

Panelists were tested for taste acuity (Appendix F) before being selected to participate in testing. During the screening session, prospective panelists were tested for their ability to taste 6-n-propyl-2-thiouracil (PROP, Sigma-Aldrich, St. Louis, Mo., U.S.A.), a compound that is generally recognized as an indicator of sensory sensitivity (Bartoshuk and others 1994). The PROP-infused filter paper (Whatman, Maidstone, U.K.) was formulated by a predesigned method (Zhao and others 2003). If panelists were unable to detect PROP, they were not selected to continue participation in the study. They were also screened for sensory acuity by performing a basic tastes test, where they were asked to identify the basic taste associated with solutions of salty (0.8 g/L sodium chloride solution, Morton Salt Inc., Chicago, IL, U.S.A.), sweet (20g/L sucrose solution, C&H Sugar Company Inc., Crockett, CA., U.S.A.), bitter (0.7 g/L caffeine solution, Fisher Scientific, Fair Lawn, NJ, U.S.A.), sour (0.6 g/L citric acid solution, Tate & Lyle, Hoffman Estates, IL, U.S.A.), and umami (0.5 g/L monosodium glutamate solution, Ajinomoto North America, Inc. Fort Lee, NJ, U.S.A.). A total of 6 solutions were presented, with spring water being presented as a blank. Panelists were allowed to continue participation in the study if they correctly identified at least 3 out of 6 solutions.

5.3.6 Sample Evaluation for Descriptive Analysis Study

Panelists attended 22 sessions in total, with 14 sessions of training (one hour each) and 8 sessions of actual testing (~30 minutes each). The first 7 training sessions focused on generating terms and references that represented attributes that were present in the soup samples from the sensory modalities of appearance, aroma, aroma-by-mouth, texture, taste, and aftertaste. All terms, term definitions, and references were generated by the panelists and were refined throughout subsequent sessions to reduce redundancy among the terms. During the term and reference generation sessions, all 24 soups samples were presented to the panelists an equal number of times. Soup samples with herbs were presented separately from soup samples without herbs during term and reference generation sessions. For the following 5 sessions, panelists established reference intensities with respect to the soup samples. Reference intensities were discussed in a round table format. Two sessions were dedicated for practice booth testing. Eight sessions were for actual booth testing. A detailed summary of the descriptive analysis panel is in Appendix G.

5.3.7 Statistical Analysis

Data from the consumer test were analyzed by Analysis of Variance (ANOVA) using SAS (Version 9.4, SAS Institute Inc., Cary, NC, U.S.A.) and XLSTAT (Version 2009, Addinsoft, New York, NY, U.S.A.) programs. Agglomerative hierarchical clustering analysis (AHC) was generated using XLSTAT. An internal preference map was generated by consumer overall liking data for the 24 soups using XLSTAT (Figures 5.1 and 5.2).

Descriptive analysis data were analyzed by ANOVA using SAS for each attribute. For attributes with significant differences across the samples, means separation was conducted using Fisher's Least Significant Difference procedure at a level of 5% using SAS. Principal component analysis (PCA) was conducted on the correlation matrix of mean intensity ratings for the significant attributes using XLSTAT. An external preference map was generated by regressing overall liking data of the four major clusters of consumers from the consumer test onto the PCA biplot of the descriptive analysis data using XLSTAT. The agglomerative hierarchical clustering (AHC) analysis was conducted using overall liking ratings of soup samples by 96 consumers. The number of clusters was calculated by the Ward's method.

5.4 Results and Discussion

5.4.1 Consumer Study

When comparing the factors for the soups (fat, sodium, herb levels), the drivers of liking were both sodium and herb levels. There was no significance difference in overall liking among soups based on the fat levels (Table 5.4). There was a significant increase difference ($p<0.01$) in overall liking in the reduced sodium versus the regular and low sodium soups (Table 5.4). There was a significant increase ($p<0.05$) in overall liking in the soups with herbs compared with the soups without herbs (Table 5.4).

Fat and sodium levels in the soups without herbs displayed several interesting findings (Table 5.5). The DF and LF soups displayed a compensation effect, where increased sodium content impacts overall liking when fat is reduced, with overall liking being the highest in the DF-RS and LF-RS soups. The overall liking of RF-DS soup was significantly higher compared to the other RF soups, also displaying the impact of overall liking in the soup system when sodium is decreased in a regular fat system. Regardless of sodium level, there was no difference in overall liking with the FF soups.

Fat and sodium levels in the soups with herbs also showed several interesting findings (Table 5.5). Herb content had no impact on liking of sodium levels in the RF soups, and the RF-RS soup had the highest overall liking. However, herb content impacted liking of soups of different sodium levels in the DF, LF and FF soups, with overall liking being the highest in low and reduced sodium content, which demonstrated that the addition of herbs in the soups compensates for the loss of saltiness in lower salt formulations.

One study which focused on the impact of herbs on overall liking and consumption of salt in retorted chicken noodle and tomato soups found that herbs decreased overall salt consumption for the retorted soups (Wang and others 2014). Soups were evaluated both before and after adding salt to the soups until the saltiness level was appropriate to the consumer. When the herb level increased, the amount of salt consumers added to the soup decreased, indicating that herbs have a role on the sodium consumption level (Wang and others 2014).

Figure 5.3 shows the dendrogram of AHC and four clusters. The subjects in Cluster 1 were 33.5% (n = 32) of the total number of consumers and was the largest cluster. Mean sample ratings for this cluster were highest in regular fat soups with regular, reduced (with herbs), and low sodium levels, and reduced fat soups with low sodium (Figure 5.4). Cluster 2 consisted of 21.9% (n = 21) of the total number of consumers. This cluster consisted of likers of reduced fat soups with reduced and low sodium content, and reduced and regular sodium content with herbs (Figure 5.5). Cluster 3 comprised of 29.2% (n = 28) of consumers. Consumers in this cluster had the highest rating for overall liking among low and fat free soups with regular and reduced sodium levels (Figure 5.6). Cluster 4 consisted of 15.6% (n = 15) of consumers. Consumers in this cluster had high ratings for both regular, reduced, and low fat soups with regular sodium content (Figure 5.7).

Cluster analysis and internal preference mapping revealed that there are consumer segments that prefer soups with decreased sodium and fat content. Study findings have concluded that a reduction of sodium by 50% or more in processed food systems are possible without affecting taste and consumer acceptability (Bertino, 1982; Garey, 1985; Witschi, 1985;

Nolan, 1983). However, the concentration of sodium alone does not determine the acceptability in a complex processed food system. With sodium interacting with other sensory components, including fats and herbs, perceptions of saltiness and acceptability are product specific (Adams, 1995).

5.4.2 Descriptive Analysis Study

A total of 18 sensory attributes were generated for the 24 soup samples (Table 5.6). Panelists were reproducible over 2 replications for 11 attributes (Table 5.7). Seven attributes showed a statistically significant difference between replications, which included: darkness (appearance, $p < 0.001$), viscous (appearance, $p < 0.05$), viscous (texture, $p < 0.001$), sour (taste, $p < 0.05$), salty (aftertaste, $p < 0.05$), sour (aftertaste, $p < 0.01$), and umami (aftertaste, $p < 0.05$). Judges were a significant source of variation in 16 out of the 18 attributes. Variation across judges is common in descriptive analysis (Stone and others 2009). Reasons for this variation could include the panelists not using the entire scale or using different parts of the scale when rating the samples (Stone and others 2009). Within each factor (fat, sodium, herb), some attributes were significantly different across samples. A significant judge by sample interaction (J×S), which represents inconsistency among the panelists, was evidenced in some of the attributes. Adjusted F-test with mixed model ANOVA, taking the judges as a random effect was conducted using the significant J×S interaction as the error term for those attributes (Table 5.8).

As the fat level varied, 16 attributes were found to be significantly different across the samples after ANOVA and adjusted F-test were conducted. Attributes which were significantly different included: darkness (appearance), viscous (appearance, texture), tomato (aroma, aroma-by-mouth), dairy (aroma, aroma-by-mouth), basil (aroma, aroma-by-mouth), thyme (aroma,

aroma-by-mouth), grainy (texture), salty (aftertaste), sour (aftertaste), and umami (taste, aftertaste).

As the sodium level varied, nine attributes were found to be significantly different across the samples after ANOVA and adjusted F-test were conducted. Attributes which were significantly different included: thyme (aroma, aroma-by-mouth), tomato (aroma-by-mouth), dairy (aroma-by-mouth), basil (aroma-by-mouth), thyme (aroma-by-mouth), grainy (texture), salty (taste, aftertaste), and umami (taste).

Twelve attributes were found to be significantly different across the samples after ANOVA and adjusted F-test were conducted as affected by the herb level. Attributes which were significantly different included: darkness (appearance), tomato (aroma-by-mouth), dairy (aroma, aroma-by-mouth), basil (aroma, aroma-by-mouth), thyme (aroma, aroma-by-mouth), viscous (texture), sour (aftertaste), and umami (taste, aftertaste).

From the PCA biplot of soups with and without herbs (Figure 5.8), Factor 1 accounted for 38.46% and Factor 2 accounted for 31.66% of the variation within the plot. Fat free herb and non-herb soups were characterized by attributes including grainy (texture), tomato (aroma-by-mouth, aroma), sour (aftertaste), and viscous (texture). Regular and reduced fat soups were characterized by dairy (aroma-by-mouth, aftertaste). Soups containing herbs were primarily characterized by the attributes that described the herb notes, basil and thyme. Regular sodium soups, regardless of fat content, were characterized by the attributes of salty (taste, aftertaste) and umami (taste, aftertaste).

From the external preference map (Figure 5.9), consumer clusters 1, 2, and 4 were regressed toward herb, salt and umami attributes. Only consumer cluster 3 was regressed toward attributes for tomato (aroma) and sour (aftertaste).

As shown in our descriptive analysis results, it has been shown that reducing sodium in processed food systems such as soups consequently decreases some prominent flavors as well as increases other prominent flavors (Mitchell and others, 2011). When the flavor of two vegetable soups (regular sodium and reduced sodium) was profiled through descriptive analysis, the regular sodium vegetable soup was strongly correlated with the attributes 'salt flavor,' 'carrot aroma', and 'overall flavor.' The reduced sodium vegetable soup was associated with a significantly reduced 'salt flavor' and 'overall flavor.' Additionally, reducing salt in the soup appeared to have the effect of intensifying other flavors present in the regular sodium soup such as 'sweet' and 'pepper' flavors (Mitchell and others, 2011).

Differences in preferences for sodium levels in processed food systems are also related both to table salt use and to total sodium intake. One study which presented panelists with tomato soup with varying sodium levels and assessed for overall liking on a 9-point hedonic scale demonstrated that those groups that preference for higher concentrations of sodium in soups was related to higher intake (Shepherd and others 1984).

5.5 Conclusions

Research results showed that sodium is one of the major drivers of liking in soups regardless of fat content. The compensation effect, in which higher levels of sodium in the lower fat soups increase overall liking, was shown in the soups without the addition of herbs. However, when herbs were added, the compensation effect was amplified, and was particularly shown to have greater effect in the reduced and low fat soups, requiring less sodium to be added. Results from the descriptive analysis study indicated that specific attributes highlighted in lower fat soups, including darkness (appearance) and grainy (texture), could warrant product reformulation to minimize these attributes and thereby increase overall liking. Attributes highlighted in lower sodium soups, including the lack of saltiness (taste and aftertaste) should also warrant product reformulation, and specifically examine the use of herbs to potentially increase these attributes. Study findings could be impacted by palate fatigue and the temperature range of the soups when served (145°F-180°F), which may have impacted taste perception. Because these findings are based on one specific model system, the findings from the study are limited to comparable food systems, such as other types of soups. In addition, the use of alternative ingredients (salted butter, low sodium tomato sauce, regular sodium tomato sauce, 1% or full fat milk) were not explored for the model creamy tomato soup. Furthermore, although findings concluded that herb content played an impact on overall liking, herb content and quantity was very specific to this model system, and warrants further investigation of appropriate levels and extending to other food systems.

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5.7 Tables and Figures

Table 5.1: Nutrient and Herb Levels of Model Retorted Tomato Soup System†

a. Nutrient levels

Nutrient Content Claim Level	Sodium (mg)	Fat (g)
Free	[redacted]	0
Low	135	2.78
Reduced	435	5.56
Regular	735	8.33

b. Herb Content and Levels

Herb	Level (g)
Rosemary	0.63
Thyme	0.63
Basil	12.59

†Amounts are based on 259.23 g serving size

Table 5.2: Soup Abbreviations

Nutrient Content of Soup	**Abbreviation**	**Nutrient Content of Soup**	**Abbreviation**
Regular Fat, Regular Sodium	RF-RS	Regular Fat, Regular Sodium, Herb	RF-RS-H
Regular Fat, Reduced Sodium	RF-DS	Regular Fat, Reduced Sodium, Herb	RF-DS-H
Regular Fat, Low Sodium	RF-LS	Regular Fat, Low Sodium, Herb	RF-LS-H
Reduced Fat, Regular Sodium	DF-RS	Reduced Fat, Regular Sodium, Herb	DF-RS-H
Reduced Fat, Reduced Sodium	DF-DS	Reduced Fat, Reduced Sodium, Herb	DF-DS-H
Reduced Fat, Low Sodium	DF-LS	Reduced Fat, Low Sodium, Herb	DF-LS-H
Low Fat, Regular Sodium	LF-RS	Low Fat, Regular Sodium, Herb	LF-RS-H
Low Fat, Reduced Sodium	LF-DS	Low Fat, Reduced Sodium, Herb	LF-DS-H
Low Fat, Low Sodium	LF-LS	Low Fat, Low Sodium, Herb	LF-LS-H
Fat Free, Regular Sodium	FF-RS	Fat Free, Regular Sodium, Herb	FF-RS-H
Fat Free, Reduced Sodium	FF-DS	Fat Free, Reduced Sodium, Herb	FF-DS-H
Fat Free, Low Sodium	FF-LS	Fat Free, Low Sodium, Herb	FF-LS-H

Table 5.3.a: Ingredient and Nutrient Composition for Model Retorted Tomato Soup System for Regular Fat and Varying Sodium Levels

Regular Fat-Regular Sodium (RF-RS)					
Ingredient	%	Grams (g)	Calories	Calories from Fat	Sodium (mg)
butter	4.05	31.5	225	225	0
water	0	0	0	0	0
milk	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.66	5.19	0	0	2045
TOTAL	100.01	777.69	465	225	2205
Serving Size		259.23	155	75	735
Regular Fat-Reduced Sodium (RF-DS)					
butter	4.05	31.5	225	225	0
water	0.29	2.28	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.37	2.91	0	0	1145
TOTAL	100.01	777.69	465	225	1305
Serving Size		259.23	155	75	435
Regular Fat-Low Sodium (RF-LS)					
butter	4.05	31.5	225	225	0
water	0.59	4.57	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.07	0.62	0	0	245
TOTAL	100.01	777.69	465	225	405
Serving Size		259.23	155	75	135

Table 5.3.b: Ingredient and Nutrient Composition for Model Retorted Tomato Soup System for Reduced Fat and Varying Sodium Levels

Reduced Fat-Regular Sodium (DF-RS)					
Ingredient	%	Grams (g)	Calories	Calories from Fat	Sodium (mg)
butter	2.7	21	150	150	0
water	1.35	10.5	0	0	0
milk	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.66	5.19	0	0	2045
TOTAL	100.01	777.69	390	150	2205
Serving Size		259.23	130	50	735
Reduced Fat-Reduced Sodium (DF-DS)					
butter	2.7	21	150	150	0
water	1.64	12.78	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.37	2.91	0	0	1145
TOTAL	100.01	777.69	390	150	1305
Serving Size		259.23	130	50	435
Reduced Fat-Low Sodium (DF-LS)					
butter	2.7	21	150	150	0
water	1.94	15.07	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.07	0.62	0	0	245
TOTAL	100.01	777.69	390	150	405
Serving Size		259.23	130	50	135

Table 5.3.c: Ingredient and Nutrient Composition for Model Retorted Tomato Soup System for Low Fat and Varying Sodium Levels

Low Fat-Regular Sodium (LF-RS)					
Ingredient	%	Grams (g)	Calories	Calories from Fat	Sodium (mg)
butter	1.35	10.5	75	75	0
water	2.7	21	0	0	0
milk	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.66	5.19	0	0	2045
TOTAL	100	777.69	315	75	2205
Serving Size		259.23	105	25	735
Low Fat-Reduced Sodium (LF-DS)					
butter	1.35	10.5	75	75	0
water	2.99	23.28	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.37	2.91	0	0	1145
TOTAL	100	777.69	315	75	1305
Serving Size		259.23	105	25	435
Low Fat-Low Sodium (LF-LS)					
butter	1.35	10.5	75	75	0
water	3.29	25.57	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.07	0.62	0	0	245
TOTAL	100	777.69	315	75	405
Serving Size		259.23	105	25	135

Table 5.3.d: Ingredient and Nutrient Composition for Model Retorted Tomato Soup System for Fat Free and Varying Sodium Levels

Fat Free-Regular Sodium (FF-RS)					
Ingredient	%	Grams (g)	Calories	Calories from Fat	Sodium (mg)
butter	0	0	0	0	0
water	4.05	31.5	0	0	0
milk	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.66	5.19	0	0	2045
TOTAL	100.01	777.69	240	0	2205
Serving Size		259.23	80	0	735
Fat Free-Reduced Sodium (FF-DS)					
butter	0	0	0	0	0
water	4.34	33.78	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.37	2.91	0	0	1145
TOTAL	100.01	777.69	240	0	1305
Serving Size		259.23	80	0	435
Fat Free-Low Sodium (FF-LS)					
butter	0	0	0	0	0
water	4.64	36.07	0	0	0
milk, skim	31.5	245	80	0	120
tomato sauce	63.8	496	160	0	40
salt	0.07	0.62	0	0	245
TOTAL	100.01	777.69	240	0	405
Serving Size		259.23	80	0	135

Table 5.4: Average Overall Liking of Model Creamy Tomato Soups Separated by Fat, Sodium and Herb Factor

Fat Levels			
Regular (8.3 g)	Reduced (5.56 g)	Low (2.78 g)	Free (0 g)
5.64[a]	5.61[a]	5.61[a]	5.48[a]
Sodium Levels			
Regular (735 mg)	Reduced (435 mg)	Low (135 mg)	
5.55[a]	5.77[b]	5.42[b]	
Herb Levels			
With (13.85 g)	Without (0 g)		
5.68[a]	5.49[b]		

Means showing a common letter are not significantly different within each ingredient, fat, sodium or herb ($\alpha = 0.05$).

Table 5.5: Average Overall Liking of Model Creamy Tomato Soups Varying in Herb, Fat, and Sodium Levels[†]

Without Herbs (0 g)											
Regular Fat (8.3 g)			Reduced Fat (5.56 g)			Low Fat (2.78 g)			Fat Free (0 g)		
RS	DS	LS	RS	DS	LS	RS	DS	LS	RS	DS	LS
5.11[b]	6.41[a]	4.44[c]	6.02[a]	5.77[a]	4.68[b]	6.25[a]	5.21[b]	5.7[ab]	5.36[a]	5.79[a]	5.12[a]
With Herbs (13.85 g)											
Regular Fat (8.3 g)			Reduced Fat (5.56 g)			Low Fat (2.78 g)			Fat Free (0 g)		
RS	DS	LS	RS	DS	LS	RS	DS	LS	RS	DS	LS
6.48[a]	5.86[ab]	5.54[b]	5.68[ab]	5.32[b]	6.19[a]	4.4[c]	6.39[a]	5.65[b]	5.05[b]	5.45[ab]	6.07[a]

[†]RS = regular sodium (735 mg), DS = reduced sodium (435 mg), LS = low sodium (135 mg)

Means showing a common letter within the grouping of three formulations as shaded are not significantly different (α = 0.05).

Table 5.6: Reference attribute, definition, preparation, reference product, and intensity for appearance, aroma, taste, aroma-by-mouth, texture, and after taste from retorted creamy tomato soup descriptive analysis

Modality	Attribute	Definition	Preparation	Reference product	Intensity
Appearance	Darkness	Appearance of color tone	15 mL in 60 mL cup	Tomato Soup, Campbell Soup Co.	9.9
	Viscous	Appearance of resistance to flow	15 mL in 60 mL cup	Jell-O Chocolate Pudding	11.9
Aroma	Tomato	Aroma of tomato	15 mL in 60 mL cup	Tomato sauce, Hunt's	11.7
	Dairy	Aroma of dairy	15 mL in 60 mL cup	Whipping Cream, Land O Lakes, Inc.	11.3
	Basil	Aroma of basil	3.0 g. in 150 mL cup	Basil, Central Illinois Produce	12.4
	Thyme	Aroma of thyme	2.0 g. in 150 mL cup	Thyme, Central Illinois Produce	12.5
Taste	Salty	Taste associated with NaCl	15 mL in 60 mL cup	2.8 g/L NaCl solution	11.8
	Sour	Taste associated with citric acid	15 mL in 60 mL cup	0.5g/L citric acid solution	11.2
	Umami	Taste associated with MSG	15 mL in 60 mL cup	0.9 g/L MSG solution	11.2
Aroma-by-mouth	Tomato	Aroma-by-mouth of tomato	15 mL in 60 mL cup	Tomato Sauce, Hunt's	13.1
	Dairy Basil Thyme	Aroma-by-mouth of dairy Aroma-by-mouth of basil Aroma-by-mouth of thyme	15 mL in 60 mL cup 15 mL in 60 mL cup 15 mL in 60 mL cup	Evaporated Milk, Carnation Basil Oil, Central Illinois Produce Thyme Solution, Central Illinois Produce	11.8 12.3 12.6
Texture	Grainy	Texture associated with presence of small particles	15 mL in 60 mL cup	Applesauce, Mott's	12.8
	Viscous	Texture associated with resistance to flow in the mouth	15 mL in 60 mL cup	Jell-O Pudding	12.6
Aftertaste	Salty	Aftertaste associated with NaCl	15 mL in 60 mL cup	2.8g/L NaCl solution	10.6
	Sour	Aftertaste associated with citric acid	15 mL in 60 mL cup	0.5 g/L citric acid solution	10.1
	Umami	Aftertaste associated with MSG	15 mL in 60 mL cup	0.9 g/L MSG solution	10.8

Table 5.7: Analysis of variance (ANOVA) for 18 sensory attributes rated for 24 retorted creamy tomato soups. F-ratios are shown for source of variation.

Modality	Attribute	R[†]	J[††]	F[†††]	S[††††]	H[†††††]
Appearance	Darkness	11.7***	0.42	580.24***	1.73	6.29*
	Viscous	5.08*	0.33	3.96**	19.72	0.19
Aroma	Tomato	2.29	19.07***	21.74***	0.89	0.13
	Dairy	0.47	8.96***	33.84***	1.01	38.19***
	Basil	0.30	14.26***	7.24***	2.74	262.30***
	Thyme	0.04	8.72***	8.82***	4.16*	302.96***
ABM	Tomato	2.57	32.65***	12.52***	3.87*	18.65***
	Dairy	0.17	23.66***	36.28***	6.13**	10.33**
	Basil	0.21	10.07***	7.91***	5.85**	309.48***
	Thyme	0.12	5.95***	6.12***	4.85**	265.63***
Texture	Grainy	0.04	33.78***	12.16***	4.28*	0.03
	Viscous	15.74***	11.20***	2.87*	0.77	13.73***
Taste	Salty	1.30	18.85***	1.76	215.73***	2.94
	Sour	4.46*	31.84***	2.23	0.97	1.04
	Umami	3.28	31.54***	2.88*	5.34**	7.66**
Aftertaste	Salty	6.06*	7.45***	4.57**	200.33***	3.49
	Sour	8.89**	24.88***	5.12**	0.42	6.22*
	Umami	5.32*	27.21***	3.24*	1.97	9.33**

[†]R = Rep; [††]J = Judge; [†††]F = Fat; [††††]S = Sodium; [†††††]H = Herb
*,**,*** stand for significance at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

Table 5.7 (continued)

Modality	Attribute	R*J	R*F	R*S	R*H	J*F	J*S	J*H
Appearance	Darkness	1.29	2.87*	0.83	9.32**	0.80	0.74	1.02
	Viscous	0.61	0.80	4.18*	0.01	0.95	0.58	0.96
Aroma	Tomato	2.89**	6.85***	0.10	2.30	1.59*	0.41	1.52
	Dairy	0.96	16.59***	3.62*	32.15***	0.59	0.40	1.50
	Basil	0.66	5.72***	2.25	18.97***	3.29***	1.43	7.61***
	Thyme	0.74	17.40***	4.43*	15.98***	1.69*	0.61	7.95***
ABM	Tomato	2.30*	6.18***	0.05	2.34	1.99**	0.84	1.33
	Dairy	1.38	17.99***	3.96*	16.36***	0.72	1.67*	2.89**
	Basil	0.54	2.44	2.27	6.44*	2.40***	1.13	10.62***
	Thyme	0.64	10.91***	3.01	8.94**	1.67*	1.23	11.05***
Texture	Grainy	1.86	3.68*	4.47*	3.28	0.54	1.03	0.60
	Viscous	1.56	1.55	4.34*	1.75	0.61	0.88	2.07*
Taste	Salty	1.87	3.19*	6.01**	0.38	0.81	4.08***	0.84
	Sour	2.31*	0.58	0.82	1.79	1.04	1.06	1.63
	Umami	2.68**	4.14**	1.34	8.03**	1.29	3.47***	0.66
Aftertaste	Salty	3.57***	8.08***	6.05**	2.43	1.18	5.37***	1.45
	Sour	2.29*	1.25	1.02	0.40	2.15***	1.50	1.40
	Umami	2.25*	3.63*	0.54	4.89*	1.90**	3.47***	1.76

[†]R = Rep; [††]J = Judge; [†††]F = Fat; [††††]S = Sodium; [†††††]H = Herb
*,**,*** stand for significance at p<0.05, p<0.01 and p<0.001, respectively.

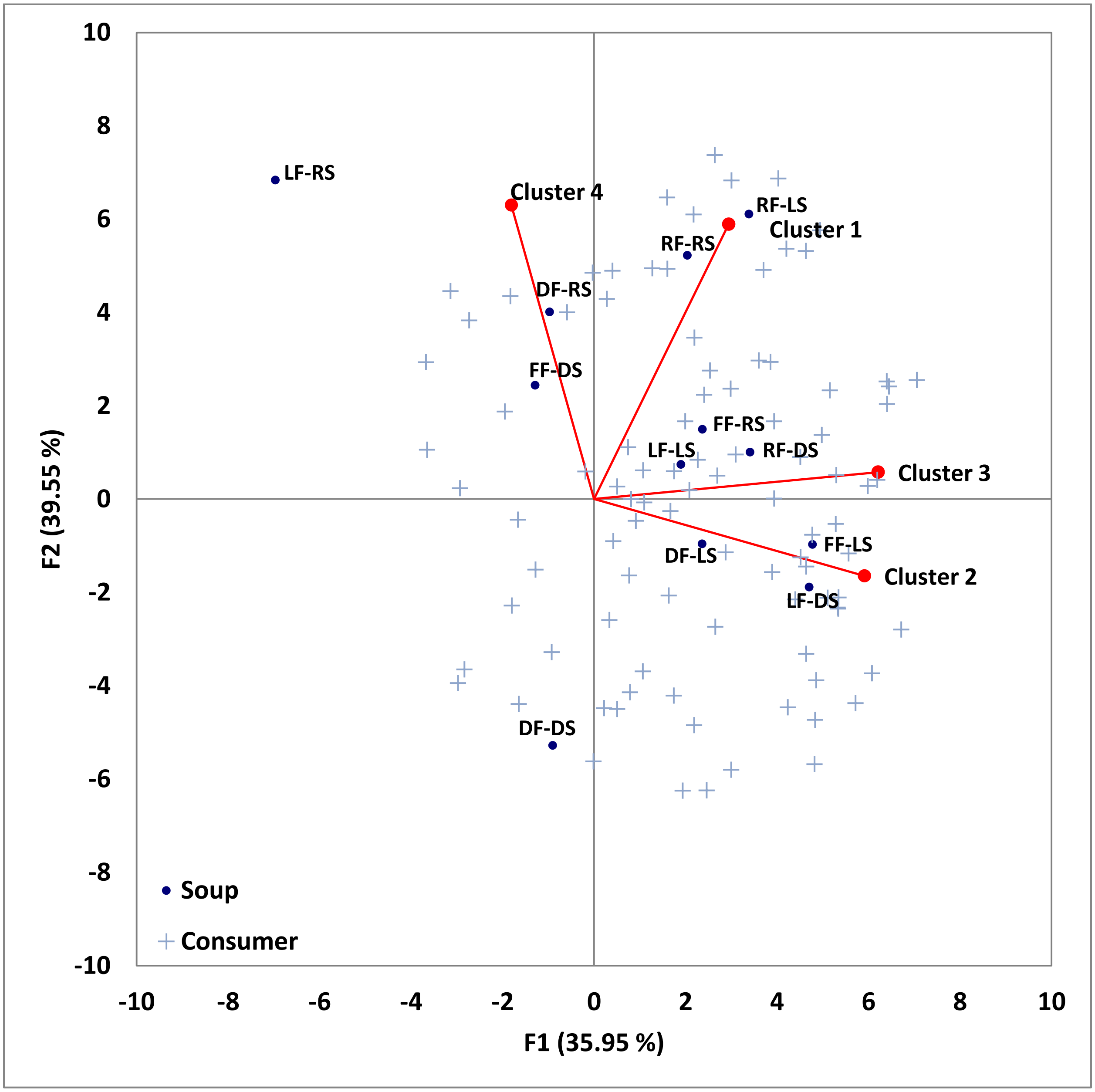
Table 5.8: Adjusted F-values using mixed model ANOVA on the soup treatments with significant judge by treatment (fat, sodium, and herb) interaction as the error term

Modality	Attribute	Adjusted F value† (Fat)	Adjusted F value (Sodium)	Adjusted F value (Herb)
Aroma	Tomato	13.67***	------------	-----------
	Basil	2.20***	------------	34.47***
	Thyme	5.22***	------------	38.11***
Aroma-by-Mouth	Tomato	6.29***	------------	------------
	Dairy	--------------††	3.67***	3.57***
	Basil	3.30***	-----------	29.14***
	Thyme	3.66***	-----------	24.04***
Texture	Viscous	--------------	------------	6.63***
Taste	Salty	-------------	52.88***	-----------
	Umami	--------------	1.54	------------
Aftertaste	Salty	--------------	37.31***	------------
	Sour	2.38***	-----------	------------
	Umami	1.71**	0.57	------------

† **F values are noted with** *,**,*** for significance at p<0.05, p<0.01 and p<0.001, respectively.

††-------: indicates adjusted F value was not calculated because judge by treatment interaction was not significant

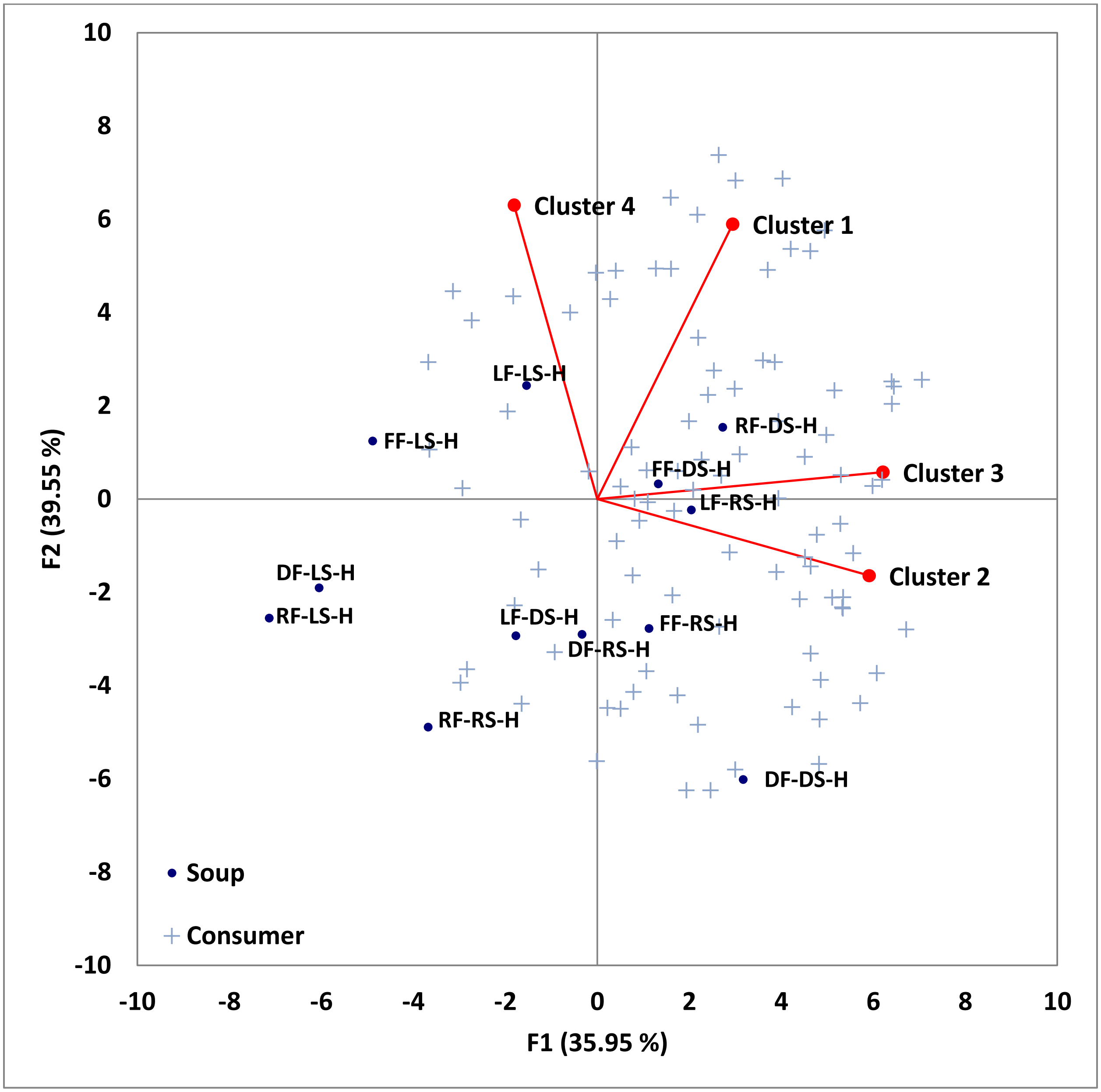
Figure 5.1: Internal Preference Map of Soup Samples without herbs by Consumers. Factors were rotated using Varimax rotation.



Factors
F = Fat
S = Sodium
H = Herb

Nutrient Levels
R = Regular
D = Reduced
L = Low
F = Free

Figure 5.2: Internal Preference Map of Soup Samples with herbs by Consumers. Factors were rotated using Varimax rotation.



Factors	Nutrient Levels
F = Fat	R = Regular
S = Sodium	D = Reduced
H = Herb	L = Low
	F = Free

Figure 5.3: Dendrogram of agglomerative hierarchical clustering (AHC) analysis based on the overall liking ratings of 96 consumers. The dotted line represents the location of truncation. The numbers of clusters were determined through Ward's method.

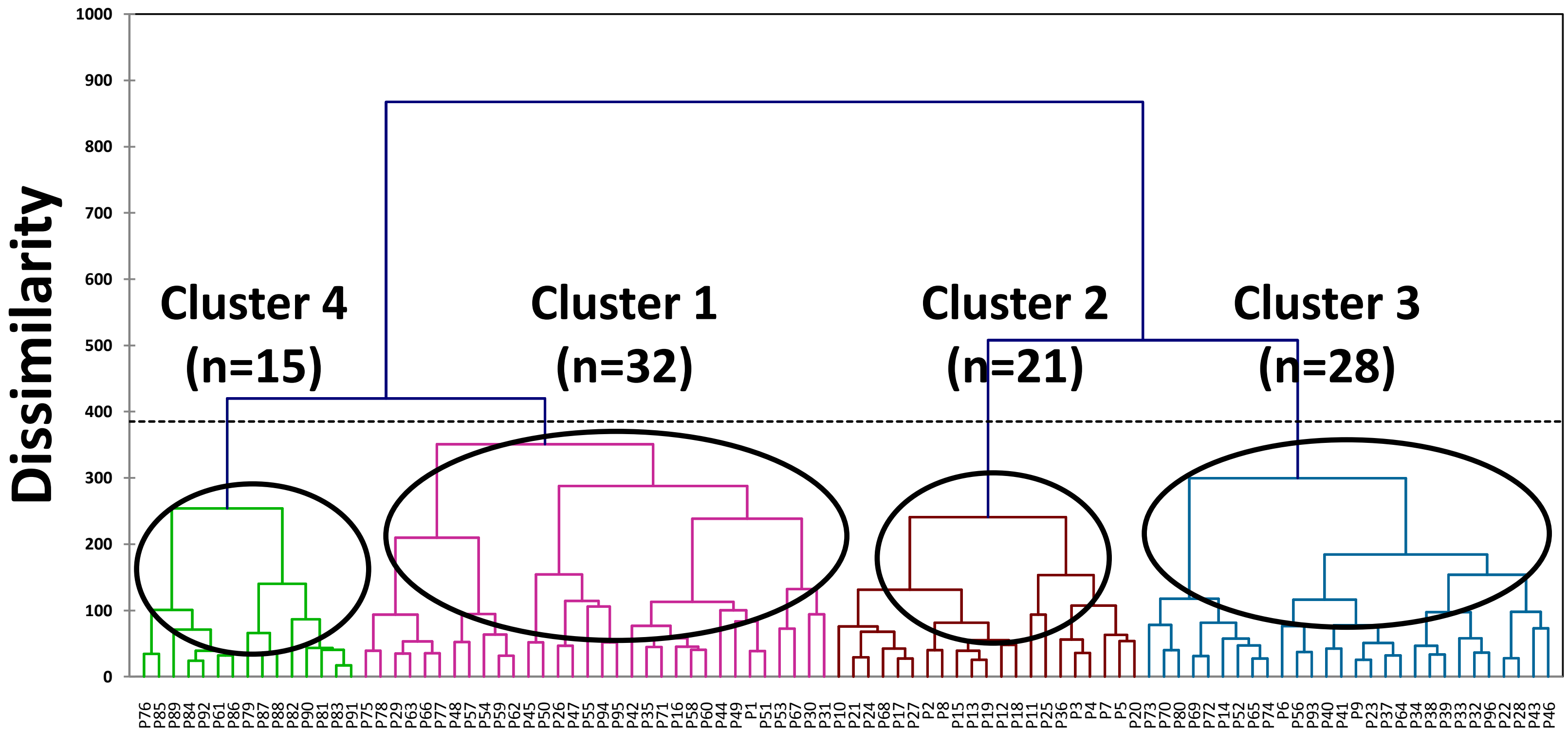
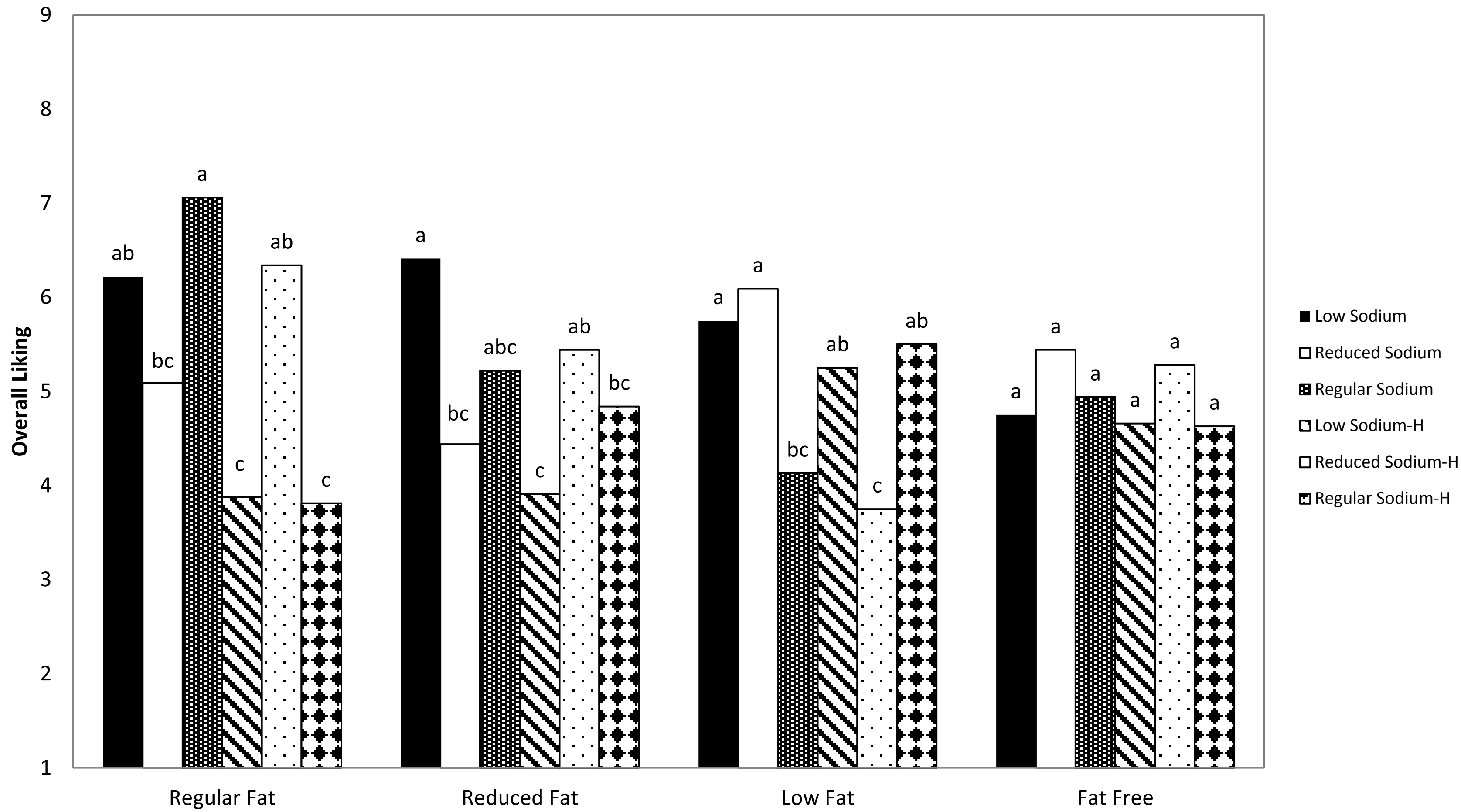
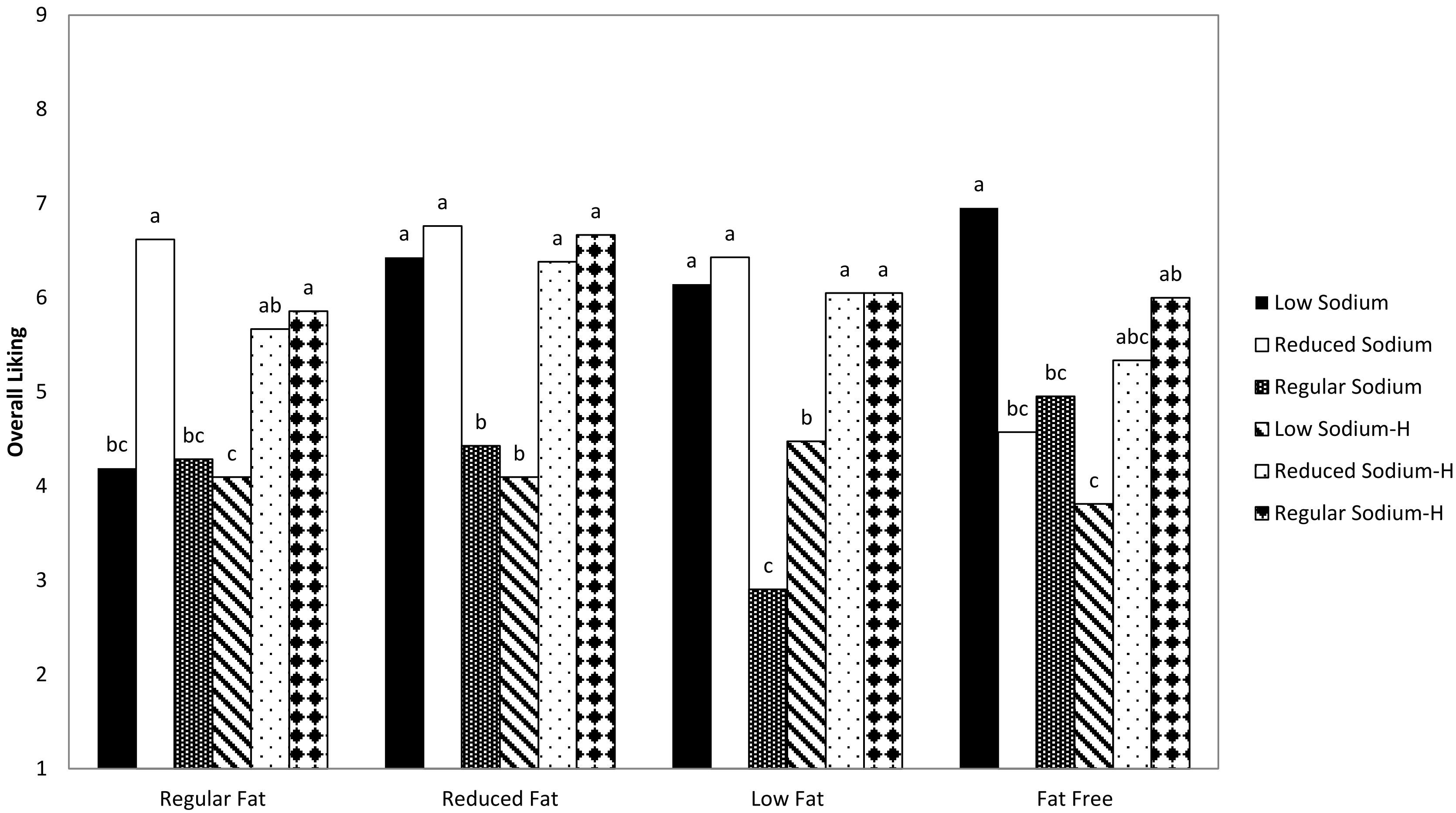


Figure 5.4: Mean Overall Liking Ratings for 24 Soups by Fat Level for Cluster 1 (n=32) based on 9-point hedonic scale



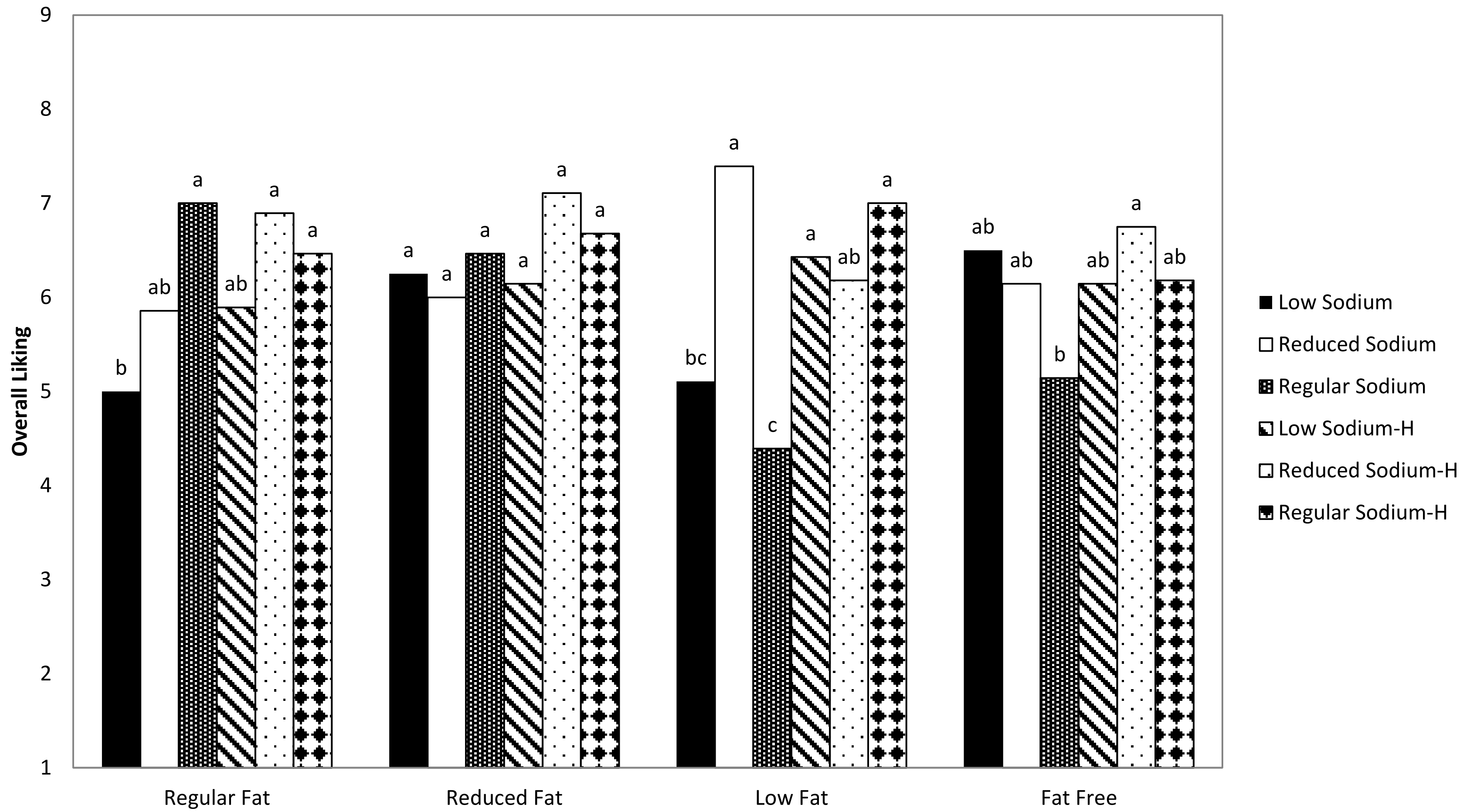
Means showing a common letter are not significantly different within the same fat level (α = 0.05).

Figure 5.5: Mean Overall Liking Ratings for 24 Soups by Fat Level for Cluster 2 (n=21) based on 9-point hedonic scale



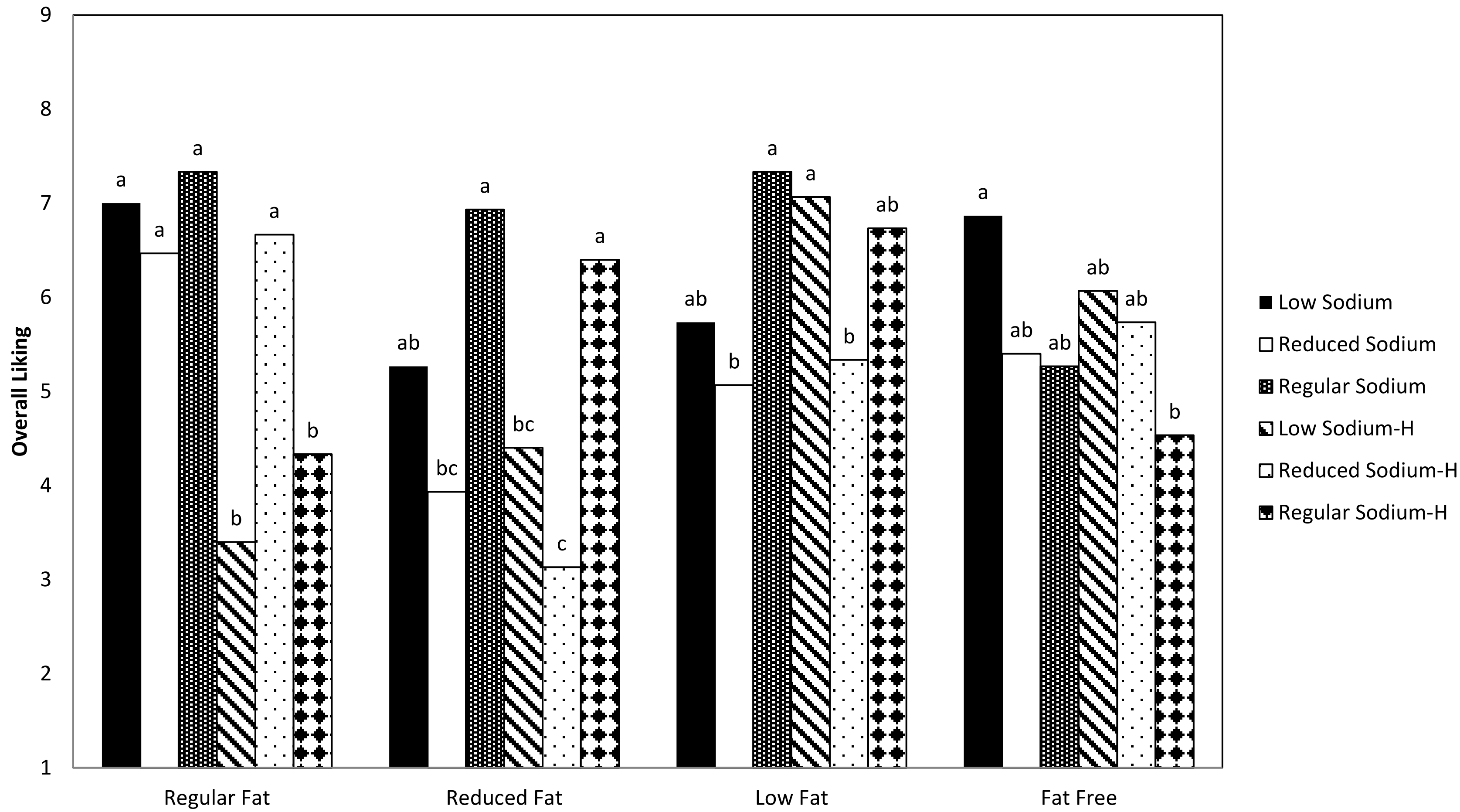
Means showing a common letter are not significantly different within the same fat level (α = 0.05).

Figure 5.6: Mean Overall Liking Ratings for 24 Soups by Fat Level for Cluster 3 (n=28) based on 9-point hedonic scale



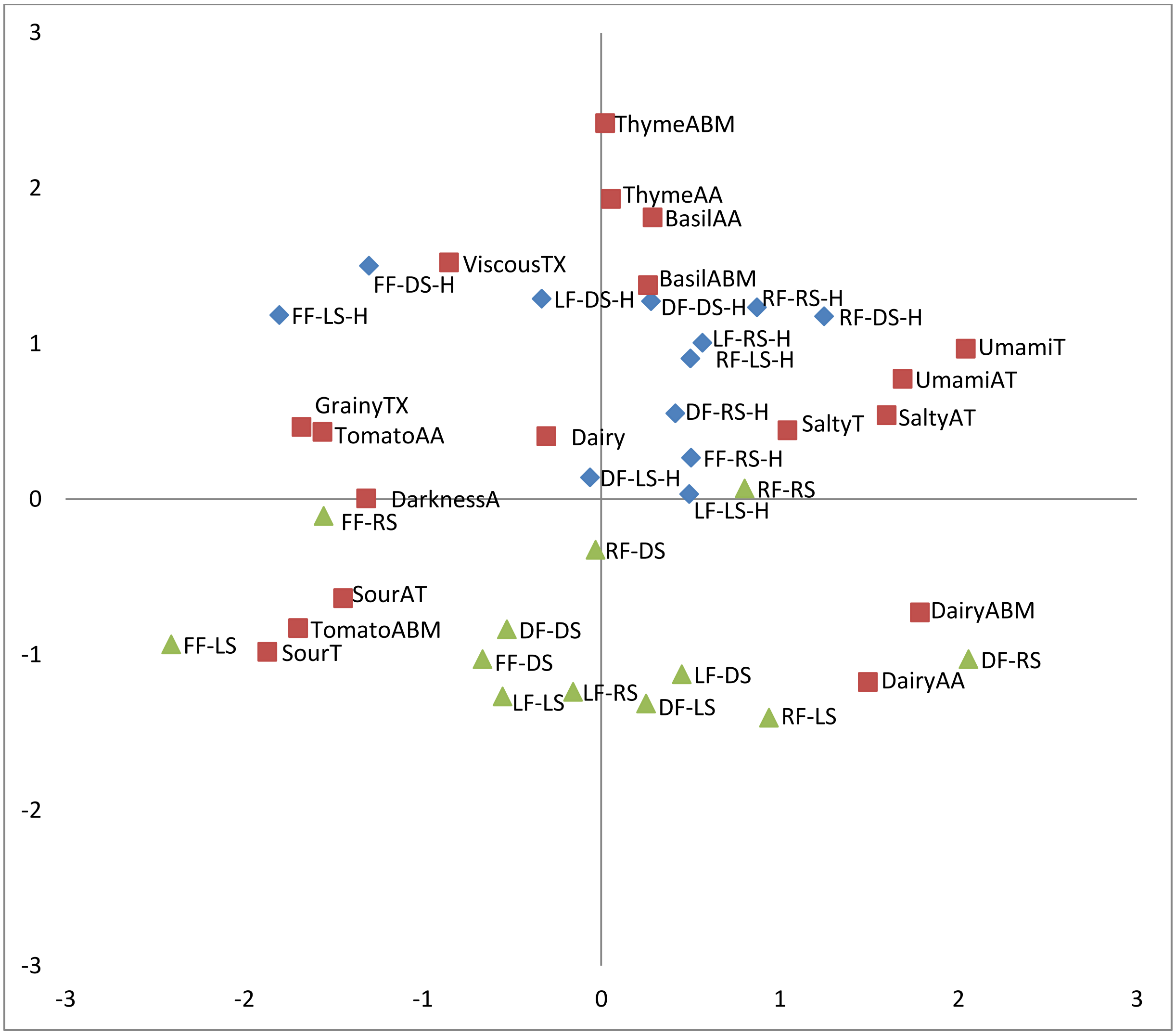
Means showing a common letter are not significantly different within the same fat level (α = 0.05).

Figure 5.7: Mean Overall Liking Ratings for 24 Soups by Fat Level for Cluster 4 (n=15) based on 9-point hedonic scale



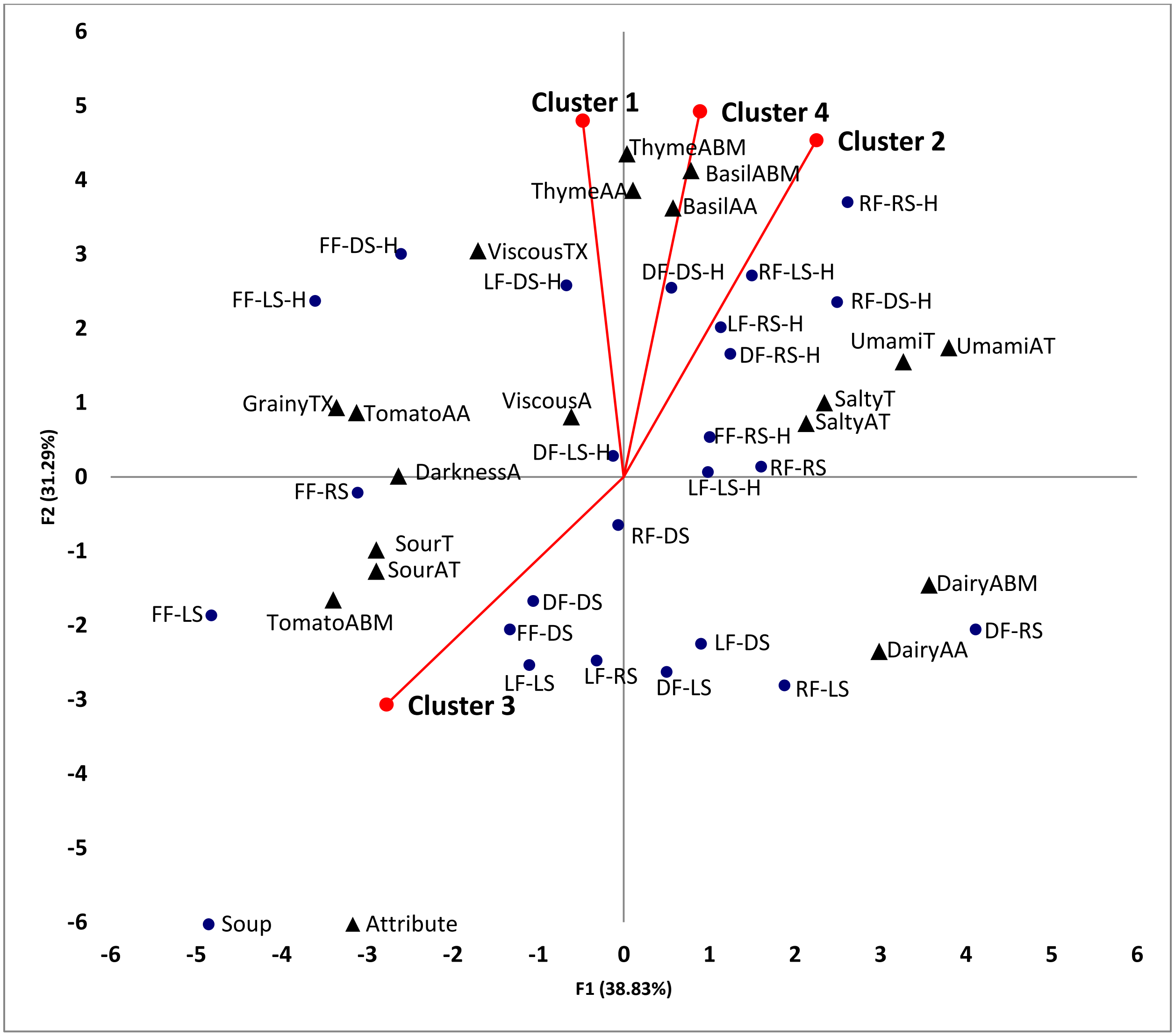
Means showing a common letter are not significantly different within the same fat level (α = 0.05).

Figure 5.8: Principal component analysis (PCA) Biplot of Factor 1 and Factor 2 by the Correlation Matrix of Mean Attribute Intensity Ratings across 24 Model Soups Factors were rotated using Varimax rotation.



Factors	Nutrient Levels	Attributes
F = Fat	R = Regular	A = Appearance
S = Sodium	D = Reduced	AA = Aroma
H = Herb	L = Low	ABM = Aroma-by-Mouth
	F = Free	TX = Texture
		T = Taste
		AT = Aftertaste

Figure 5.9: External preference mapping for 24 creamy tomato soups. The overall liking ratings from 96 consumers were regressed on the principal component analysis biplot of descriptive analysis.



Factors
F = Fat
S = Sodium
H = Herb

Nutrient Levels
R = Regular
D = Reduced
L = Low
F = Free

Attributes
A = Appearance
AA = Aroma
ABM = Aroma-by-Mouth
TX = Texture
T = Taste
AT = Aftertaste

Chapter 6: Efficacy of Sodium and Fat Labeling and its Contributions to Consumer Acceptability and Food Choice

6.1 Abstract

Food products with decreased dietary sodium and fat are recommended for consumers with hypertension (Wofford and others, 2008). Labeling information is important in order for consumers to make choices that align with nutrition therapies. However, labeling information may not cause consumers to purchase lower sodium and fat food products due to consumer expectations for taste. The study objective was to relate prior perception of nutritional labels, sensory acceptability, and nutrition labeling formats. Ninety panelists participated in a five-part study utilizing a model creamy tomato soup system with three levels of fat and sodium; regular, reduced, and low. The five-part study included a 1) survey to determine prior perception of nutritional labels, 2) consumer acceptability testing of soup samples with and without nutrient content information, 3) expected consumer acceptability testing of soup samples based solely on nutrient content information, 4) comparative evaluation of labels with verbal and visual nutrient content information, and 5) sorting activity of nutrient content information using verbal and visual labels. Study results indicated that presenting nutrient content information along with the actual soup sample did not impact consumer sensory acceptability. However, when labeling information was provided without the actual soup sample, the expected liking reported by the consumer was decreased. There was no difference in comprehension of verbal and visual labels for nutrient content. Study findings demonstrate that hypertensive populations are willing to consume processed food products lower in sodium and fat, which justifies the direction toward food reformulations.

Key words: nutrition labeling, sodium, fat, sensory, soup

Practical Applications:

Hypertensive individuals who are overweight or obese are recommended to consume reduced quantities of both dietary sodium and fat. Food products reduced in sodium and fat while maintaining consumer acceptance are desirable. Results indicate that providing labeling information with the food product has no impact on consumer acceptance in the context of this study, in which processed soup and reduced fat and sodium labeling were tested. However, consumer acceptance is decreased for labels displaying lower amounts of sodium and fat based solely on labeling information without actual sampling of the product, which simulates a product selection setting at a grocery store. Understanding the impact of labeling information on consumer acceptance would lead to an increase in the number of successful products reduced in dietary fat and sodium.

6.2 Introduction

Over 78 million US adults have hypertension, and there is increasing evidence relating high sodium consumption to hypertension (Go and others, 2013). The 2010 Dietary Guidelines for Americans recommends a daily dietary sodium consumption of ≤ 1500 milligrams (mg) for individuals with hypertension, a notable decrease from the average daily sodium consumption of 3400 mg.

Processed food choices account for over 77% of the average American's daily sodium consumption (CDC, 2010; Mattes, 1991). A reduction of sodium content in processed foods has been recommended by many scientific organizations (Durack and others, 2008; Hutton, 2002). Weight loss has also been recommended for hypertensive individuals, as over 70% of hypertensive individuals are either overweight or obese (Whelton and others, 2002).

Comprehension of nutrition information displayed on food products is critical for hypertensive populations, specifically fat and sodium content. However, a survey conducted to assess consumers' knowledge base of label claims revealed the majority of survey participants were unable to correctly answer questions regarding sodium and fat label claims (Cox and others, 2015).

It has been hypothesized that increased comprehension of nutrition information among consumers could subsequently aid in increased selection of food products reduced in fat and sodium content by overweight and obese hypertensive consumers. However, taste has been deemed as the most important factor regarding food choice (Mitchell and others, 2011; Glanz and others, 1998). As perception of healthiness in a food product is increased, perception of tastiness is decreased (Raghunathan and others, 2006).

In its strategies for sodium reduction, the Institute of Medicine highlighted recommendations for front-of-package labeling, and an emphasis on visual clarity and ability to convey meaning for health information without providing written information (IOM, 2010). With currently no standard requirements for front of package labeling, the development of a US federal standard for front of package labeling and the most effective formats have been examined (Hersey and others, 2013). The multiple traffic light label is a type of front of package label in which nutrient content is provided through a color scheme (Herpen and others, 2011). Red color would indicate a high quantity of a nutrient, yellow or amber would indicate a medium quantity of a nutrient, and green would indicate a low quantity of a nutrient. Studies have found that the multiple traffic light label can help consumers understand and accurately identify healthier products (Hersey and others, 2013).

Though products lower in sodium and fat are healthier options for consumers with health conditions, prior conceptions of taste may prevent these products from wanting to be purchased by consumers. Further evaluation into techniques in which low sodium and fat food systems can have increased sensory acceptability for consumers warrants further examination. With the increased popularity of front-of-package labels, further examination into consumer comprehension of visual and verbal labels and the influence of labels on consumer purchasing behavior needs further research.

The overall goal of this study was to gain a better understanding of the link across prior perception of sodium and fat labels, sensory acceptability of soups with different levels of sodium and fat, and sodium and fat labeling formats. In order to accomplish the overall goal, the specific objectives were to: 1) determine acceptance of soups varying in sodium and fat levels in blind condition to establish baseline, 2) determine prior perceptions of sodium and fat labels, 3) evaluate the influence of sodium and fat labels on sensory acceptability in a model soup system, and 4) determine effective sodium and fat label formats by comparing verbal and visual labels. We hypothesized that, due to the importance of taste, when labels are presented with the sample, overall liking will be decreased in reduced and lower fat samples. We further hypothesized that consumers would be able to comprehend visual labels more quickly and accurately than verbal labels.

6.3 Materials and Methods

6.3.1 Subjects

Participants were recruited through flyers posted on the University of Illinois campus and email listserv for departments and faculty and staff. Participants were recruited for a five-part study. Prior to participating in the study, individuals completed a preliminary survey (Table 6.1). The preliminary survey was conducted online through Qualtrics Survey Software LLC (Provo, UT, U.S.A.).

The survey included questions regarding purchase preferences, knowledge of nutrient intakes, and the influence of nutrition information on food packaging. The survey also included demographic questions, and contact information was requested from the participants so they could complete the remaining portions of the study. In order to target individuals who are potentially concerned with fat and sodium nutrient claims, participants were asked if they had been medically diagnosed as hypertensive or pre-hypertensive, or if they had a family history of hypertension or pre-hypertension. Participants who were medically diagnosed or had a family history of hypertension or prehypertension and completed the survey were eligible to then participate in the 5-part study. There were 90 participants who completed the preliminary survey and were eligible to participate in the 5-part study. Twenty were medically diagnosed as hypertensive, 5 were medically diagnosed as pre-hypertensive, and 64 had a family history of hypertension.

6.3.2 Sample Information

Creamy tomato soup was selected as the model system. Soups have been reported as one of the ten processed food categories which contribute 44% of dietary sodium (CDC, 2012). Additionally, a model soup system provides a medium in which fat and sodium levels can be easily modified (Cox and others, 2015).

Nine model creamy tomato soups were prepared with 3 levels of fat and 3 levels of sodium (regular, reduced, low). The reduced and low levels for fat and sodium content in the soups were based on the US Food and Drug Administration (FDA) nutrient content claims guide (FDA, 2013). Table 6.2 defines the specific content of the different levels of fat and sodium for the soups. Soup ingredient information is provided in Table 6.3.

The soups were prepared in a steam kettle and filled in standard No. 1 (295.74-mL capacity) metal cans (House of Cans, Lincolnwood, IL). The cans were processed in a rotating retort (Sterilmatic, JBT FoodTech, Madera, CA, U.S.A.) to sterilize the model soup at 121.1°C. The processing time (28 minutes) was determined based on time-temperature curves of each model soup sample using MPIII data loggers (Mesa Laboratories, Lakewood, CO, U.S.A.).

6.3.3 Procedure

Parts 1 through 5 of the study were conducted on the University of Illinois campus, Bevier Commons (905 South Goodwin Avenue, Urbana, IL 61801), which is a study hall type of location where people typically consume foods. Consumer testing was conducted through

Qualtrics Survey Software LLC (Provo, UT, U.S.A.). Testing was presented on tablets (Nexus Android Tablet, Asus, Fremont, CA). Paper ballots were presented to panelists who had technological challenges and were unable to use the tablets. From the 90 panelists that were recruited, 89 participants completed all 5 parts of the study. Upon completion of all five parts of the study the panelists received $30.

Part 1: Overall Liking of Creamy Tomato Soups without Labeling Information

Participants evaluated nine model creamy tomato soups for overall liking. Participants were presented with a 30 mL sample of the soup in a 60 mL capacity Styrofoam bowl. Participants were instructed to taste the sample, and rate the sample for overall liking on a 9-point hedonic scale. Participants were instructed to follow a rinse protocol of rinsing with carbonated water, warm water (38-49°C), and room temperature water before evaluating each sample.

Soup samples were assigned 3-digit randomized codes. The order of sample presentation was randomized by the Williams design. Soups were presented at a temperature range between 60-74°C.

Part 2: Expected Overall Liking of Creamy Tomato Soups Based on Labeling Information

Participants evaluated nine creamy tomato soup labels that displayed sodium and fat content. Participants were asked to look at the sodium and fat content on the soup label, and rate for overall liking of the expected perceived taste of the soups based solely on label information. Soup labels were assigned 3-digit randomized codes, and the presentation order of soup labels was randomized (Figure 6.1).

Part 3: Overall Liking of Creamy Tomato Soups with Labeling Information

Participants evaluated nine model creamy tomato soups for overall liking with sodium and fat content information provided. As in part 1, participants were presented with a 30 mL sample of the creamy tomato soups in a 60 mL capacity Styrofoam bowl.

Participants were instructed to view the label that was presented with the soup sample that displayed the sodium and fat content of the soup. Panelists were, then, asked to rate the sample for overall liking on a 9-point hedonic scale. Participants were instructed to follow a rinse protocol of rinsing with carbonated water, warm water (38-49°C), and room temperature water before evaluating each sample.

All nine soups samples were presented to the panelists at the same time, but evaluation of the soups were conducted monadically. Soup samples were assigned 3-digit randomized codes, and the order of sample presentation was randomized by the Williams design. Soups were presented at a temperature range between 60-74°C.

Part 4: Preference between Verbal and Visual Labels

Participants were presented with two No. 1 (295.7 mL capacity) cans displaying two types of labels (Figures 6.2 and 6.3). One label contained a verbal explanation of the sodium and fat content in the soup. The other label contained a visual explanation of the sodium and fat content in the soup, which was similar to the traffic light labeling system (Van Herpen and others, 2011; Hershey and others, 2013). Both labels displayed a reduced fat and reduced sodium content. The verbal label reflected the current state of food labeling found on commercial cans. The visual label was developed based on a visual traffic light labeling scheme, and only displayed fat and sodium content (FSA, 2007). Participants were asked to select the soup can label they preferred.

Part 5: Sorting Activity between Verbal and Visual Labels

Participants were presented with a set of nine verbal or visual labels. Once provided with the set of verbal or visual labels, panelists were asked to sort the labels from highest fat or sodium content to lowest fat or sodium content. The order of presentation of the type of label (verbal or visual) and the sorting of nutrient (fat or sodium) was randomized across the panelists using the Williams design.

6.3.4 Statistical Analysis

Consumer test data were analyzed using Microsoft XLSTAT (Version 2013: Addinsoft USA, New York, NY). Analysis of variance (ANOVA) was conducted for study parts 1, 2 and 3, and the calculated probabilities obtained from the analysis were compared to the significance level of 0.05. Fisher's least significant difference (LSD) was conducted when a significant difference was determined by ANOVA. Binomial test was conducted on study part 4, and the preference data were analyzed using IFPrograms (The Institute for Perception, Richmond, VA, U.S.A.)

6.4 Results and Discussion

Table 6.4 lists all soup samples and corresponding abbreviations. When examining overall liking of the soups without labeling information, both sodium and fat content were drivers of overall liking (Table 6.5). The low sodium (LS) soups were significantly less liked ($p \leq 0.05$) compared to the other sodium levels. The reduced fat (DF) and low fat (LF) soups received significantly lower overall liking ratings compared to the regular fat (RF) soups. Within the fat levels, sodium levels were found to impact overall liking (Table 6.6)). There was a significant decrease in overall liking of the LS soups across all fat levels. Within the sodium levels, there was no significant difference in overall liking across fat levels (Table 6.7)

When expected overall liking was evaluated with only the labels without tasting of the samples, both sodium and fat content were drivers of expected overall liking (Table 6.5). The LS soups were significantly decreased in expected overall liking compared to the RS soups. The LF soups were significantly decreased in overall liking compared to the RF soups. Within the fat levels, there was no significant difference in the expected overall liking across the different soup labels across sodium levels (Table 6.6). Within the sodium levels, there was no significant difference in expected overall liking across fat levels (Table 6.7).

For the evaluation of overall liking with labeling information provided, sodium and fat content were also drivers of overall liking (Table 6.5). The LS soups were significantly decreased in overall liking compared to the other sodium levels. The LF soups were significantly decreased in overall liking compared to the RF soups. Within all fat levels, there was a significant decrease in overall liking of the LS soups (Table 6.6). Within the sodium levels, there was no significant difference in overall liking across fat levels (Table 6.7).

Although labels intend to attract consumers to purchase healthy products, they may also result in decreased purchasing for consumers who select based on taste more than health (Raghunathan and others, 2006; Liem and others, 2012). While labeling information has no impact on overall liking for this particular product, the case may not be the same in other food systems. In the preliminary study, survey participants were asked to rate five different potato chip packages on their expected taste based on the nutrient content information provided. The rating was based on a 9-point scale where the lower end of the scale indicated ‘bad,’ the middle of the scale indicated ‘neutral,’ and the higher end of the scale indicated ‘good.’ Three potato chip labels were based on fat content. Based on the regular potato chip label, 52% of survey respondents gave greater than 7 for expected taste. For the low fat potato chip label, over 50% of respondents were neutral (rating between 4-6) as to its expected taste. The fat free potato chip label received a rating of less than 3 by 52% of participants for its expected taste. Two potato chip labels were based on sodium content. For the light sodium potato chip label, over 50% of survey respondents were neutral about expected taste. For the low sodium potato chip label, 54% of participants provided neutral ratings for expected taste.

Another study examined the effects of health labels on expected and actual taste perception of soup (Liem and others, 2012). Participants tasted four chicken soups that were exactly the same in formulation, and rated their expected and perceived taste based on different labels and logos. The control package stated "chicken soup," and the other three packages contained either a label which stated "reduced in salt," a "Healthy Choices Tick logo," or both the reduced salt label and logo. Though there was no significant difference found in expected liking among the soups, the soup with the "Healthy choices Tick logo" scored higher in overall liking than the "reduced in salt" and "reduced salt label and logo." There was no significant difference found in liking among the soups when tasted (Liem and others, 2012).

An additional study, which focused on the effect of health information according to product type, examined consumer responses to regular and reduced fat content information in four different products. From an online survey which recorded perception of pleasantness of regular and reduced fat yogurt, margarine, chocolate bars, and frankfurters on a 7-point hedonic scale from 253 consumers resulted in different perceptions based on the product. Consumer perception of pleasantness was divided into groups of concern for health. In the low concern for health group, information regarding reduced fat content decreased pleasantness ratings when compared to the regular fat counterparts for yogurt and frankfurters. For participants who noted a high concern about health, pleasantness ratings increased for content information for reduced fat margarine than regular fat margarine. This outcome was also observed in a prior sensory experiment in which reduced-fat spreads were preferred when nutrient information was reported among consumers who were concerned about their health (Kahkonen and others, 1996). Regardless of health concern, pleasantness ratings for reduced fat chocolate decreased, implying that for some food products, including chocolate, consumers are less willing to compromise on taste (Rozin and others, 1991; Kahkonen and others, 1999).

When participants were asked to select the soup can label that they preferred, 42% of panelists preferred the verbal label, and 58% of panelists preferred the visual label. There was no significant difference between the preference of the verbal and visual label ($p = 0.137$). When asked to sort soup cans with verbal labels from highest to lowest fat content 77 out of 89 panelists sorted the cans correctly. With the visual labels, 80 out of 89 panelists sorted from highest to lowest fat content correctly. When cans with verbal labels were sorted from highest to lowest sodium content, 75 out of 89 participants sorted the cans correctly, and 82 out of 89 panelists sorted the cans with visual labels from highest to lowest sodium content correctly. When the average time of sorting the labels was compared, there was no significant difference in the time to sort the verbal and visual labels for fat (verbal - 39 seconds, visual – 32 seconds) and sodium (verbal - 38 seconds, visual – 33 seconds.

Although there was no difference in consumer comprehension and efficiency between the verbal and visual labels from our study, multiple studies have found that visual labels aid in consumer comprehension of healthier products (Hersey and others, 2013). Out of fifteen studies examining consumer understanding of front of package labels through use of color versus no color for displaying nutrient levels in products, eight out of the fifteen studies found that front of package labels with color more easily allowed consumers to determine and rate the healthiness of a product (Hersey and others, 2013). One of the studies found that consumers were able to provide more correct responses regarding nutrient levels in foods when examining labels with traffic light compared with labels without color.

When comparing nutrition factors to consider when making food purchases in the grocery store, the participants ranked sodium and fat content 4^{th} and 2^{nd}. Calorie content was ranked as the most important factor. The majority (91%) of participants stated that they look for nutrition-related information on food packages. The majority (70%) of participants also stated that they look for nutrition-related information more than 50% of the time when grocery shopping.

The preliminary survey showed that over half of survey participants were knowledgeable about daily recommended dietary intakes for sodium and fat, with 59% selecting "less than 2400mg" for sodium and 52% selecting "less than 65g" for fat. In addition, preliminary survey results showed 10% of participants primarily look for nutrition-related information on the front of the food package, while 90% look on the back of the food package. Labels providing the traffic light scheme on the front of the package label would effectively direct consumers to quickly identify foods that would meet daily recommended dietary intakes for sodium and fat.

6.5 Conclusions

Study findings show that overall liking of creamy tomato soups are did not significantly change when tasted blind versus along with a label. Further research can be conducted to examine if consumers, when tested for consumer acceptability of lower sodium and fat food products, would actually purchase the product. Testing design would include consumers being presented with samples of a food product of varying sodium and fat levels. The samples would be presented blindly, and then along with the labeling information. Upon completion of testing, consumers would be asked to purchase one of the food product, and varying sodium and fat levels of the food product would be presented in a mock shopping condition. Though increased consumer comprehension of both visual and verbal labels is warranted, further research regarding if increased consumer comprehension of labels will impact consumer purchasing of healthier products is also warranted. Testing design could include consumers being presented with food products with varying levels of sodium and fat with both visual and verbal labels. By presenting both types of labels to consumers, additional research could show if there is a preference between verbal and visual labels, and if either label impacts consumer purchasing of lower sodium and fat food products. This testing design could involve consumers being place in a mock grocery store environment, and provided with visual and verbal labels of various food categories to examine if labeling type has an impact on purchasing.

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6.7 Tables and Figures

Table 6.1: Preliminary Survey Questions

Questions	Selection of Responses Listed
1. Have you been diagnosed by a physician as hypertensive or pre-hypertensive?	• Yes, I have been diagnosed as hypertensive. • Yes, I have been diagnosed as pre-hypertensive. • No, I have not been diagnosed as hypertensive or pre-hypertensive.
2. If you have been diagnosed by a physician as hypertensive or pre-hypertensive - What year were you first diagnosed as being hypertensive or pre-hypertensive?	• I was first diagnosed in the year:
3. Do you have a family history of high blood pressure or hypertension?	• Yes • No
4. What are the most important nutrition factors for you to look at or consider when you are buying food in the grocery store? Please rank the following factors from 1 to 6 where 1 = MOST IMPORTANT, 2 = SECOND MOST IMPORTANT, . . . , and 6 = LEAST IMPORTANT.	• Calories • Fat • Sodium • Protein • Fiber • Sugar
5. Do you look for health or nutrition-related information on food packages?	• Yes • No If No Is Selected, Then Skip To Question 8
6. Where do you primarily look for health or nutrition-related information on food packages?	• Front of the food package (Health or Nutritional Label Claim) • Back of the food package (Nutrition Facts Panel) • Other ______________________
7. On a scale from 0% of the time to 100% of the time, how often do you look for health or nutrition-related information on food packages when grocery shopping?	• Percent of Time Spent Looking for Health or Nutrition-Related Information

Table 6.1 (continued)

Questions	**Selection of Responses Listed**
8. Do you know the recommended daily intake of sodium based on a 2,000 calorie diet for the average American?	• Yes • No
9. To the best of your knowledge, what is the recommended daily intake of sodium based on a 2,000 calorie diet for the average American? Even if you are unsure, please provide your best estimate.	• Less than 4800 milligrams of sodium daily, equivalent to roughly 2 teaspoons of salt • Less than 3600 milligrams of sodium daily, equivalent to roughly 1 1/2 teaspoons of salt • Less than 2400 milligrams of sodium daily, equivalent to roughly 1 teaspoon of salt • Less than 1500 milligrams of sodium daily, equivalent to roughly 1/2 teaspoon of salt
10. Do you know the recommended daily intake of fat based on a 2,000 calorie diet for the average American?	• Yes • No
11. To the best of your knowledge, what is the recommended daily intake of fat based on a 2,000 calorie diet for the average American? Even if you are unsure, please provide your best estimate.	• 100 grams of fat daily, or roughly 45% of total daily calories • 65 grams of fat daily, or roughly 30% of total daily calories • 30 grams of fat daily, or roughly 15% of total daily calories
12. Recently, a reduced fat version of these potato chips was introduced in the market. How would you expect the sodium content to change in the reduced-fat version of the product compared to the regular version?	• I would expect the sodium content to be increased in the reduced-fat version. • I would expect the sodium content to be decreased in the reduced-fat version. • I would expect the sodium content to be the same in the reduced-fat and regular versions.
13. How would you expect the fat content to change in the reduced-fat version of the product compared to the regular version?	• I would expect the fat content to be increased in the reduced-fat version. • I would expect the fat content to be decreased in the reduced-fat version. • I would expect the fat content to be the same in the reduced-fat and regular versions.

Table 6.1 (continued)

Questions	**Selection of Responses Listed**
14. Recently, a reduced fat version of these potato chips was introduced in the market. How would you expect the sugar content to change in the reduced-fat version of the product compared to the regular version?	• I would expect the sugar content to be increased in the reduced-fat version. • I would expect the sugar content to be decreased in the reduced-fat version. • I would expect the sugar content to be the same in the reduced-fat and regular versions.
15. How would you expect the number of calories to change in the reduced-fat version of the product compared to the regular version?	• I would expect the number of calories to be increased in the reduced-fat version. • I would expect the number of calories to be decreased in the reduced-fat version. • I would expect the number of calories to be the same in the reduced-fat and regular versions.
16. On a scale from 1 to 9, how likely or unlikely would you be to eat potato chips? Please click and drag the slider to the appropriate number.	• Likelihood of Eating Potato Chips
In the following section, you will be asked to rate five different potato chips packages on their expected taste and expected healthfulness. Each of the five packages are different, so be sure to read the labels carefully.	
17. On a scale from 1 to 9, how would you rate this package of regular potato chips in terms on each of the following dimensions?	• Expected TASTE • Expected HEALTHFULNESS
18. On a scale from 1 to 9, how would you rate this package of low sodium potato chips in terms on each of the following dimensions?	• Expected TASTE • Expected HEALTHFULNESS

Table 6.1 (continued)

Questions	Selection of Responses Listed
19. On a scale from 1 to 9, how would you rate this package of light sodium potato chips in terms on each of the following dimensions?	• Expected TASTE • Expected HEALTHFULNESS
20. On a scale from 1 to 9, how would you rate this package of low fat potato chips in terms on each of the following dimensions?	• Expected TASTE • Expected HEALTHFULNESS
21. On a scale from 1 to 9, how would you rate this package of fat free potato chips in terms on each of the following dimensions?	• Expected TASTE • Expected HEALTHFULNESS
22. What is your gender?	• Male • Female
23. What is your current age in years?	• 18 to 29 years • 30 to 39 years • 40 to 49 years • 50 to 59 years • 60 to 69 years • 70 years or older
24. What is your annual household income before taxes?	• Less than $25,000 • $25,000 to $49,999 • $50,000 to $74,999 • $75,000 to $99,999 • $100,000 or more

Table 6.1 (continued)

Questions	Selection of Responses Listed
25. What is your current highest level of education?	• Some high school • High school diploma / GED • Some college • Associates/technical degree • Bachelor's degree • Post-Graduate or Professional Degree (M.S., M.A., Ph.D., J.D., M.D.)
26. Which of the following best describes your race?	• White or Caucasian • Black or African American • Asian or Pacific Islander • Native American • Hispanic • More than one race • Some other race
27. What is your current height?	• 5 ft. 0 in. or less • 5 ft. 1 in. - 5 ft. 6 in. • 5 ft. 7 in. - 6 ft. 0 in. • 6 ft. 1 in. - 6 ft. 6 in. • 6 ft. 7 in. - 7 ft. 0 in.

Table 6.1 (continued)

Questions	Selection of Responses Listed
28. What is your current weight?	• 110 lbs. or less (50 kg or less) • 111 lbs. - 125 lbs. (50.5 kg - 56 kg) • 126 lbs. - 140 lbs. (57 kg - 63 kg) • 141 lbs. - 155 lbs. (64 kg - 70 kg) • 156 lbs. - 170 lbs. (71 kg - 77 kg) • 171 lbs. - 185 lbs. (77.5 kg - 84 kg) • 186 lbs. - 200 lbs. (84.5 kg - 90 kg) • 201 lbs. - 225 lbs. (91 kg - 102 kg) • 226 lbs. - 250 lbs. (102.5 kg - 113 kg) • 251 lbs. - 275 lbs. (114 kg - 125 kg) • 276 lbs. - 300 lbs. (125.5 kg - 136 kg) • More than 300 lbs. (more than 136 kg)
29. Are you the primary shopper in your household?	• Yes • No
30. Do you buy food for other individuals (spouse, children, parents, etc.) who have health concerns?	• Yes • No
31. Which of the following health conditions are in your family history? Please check all that apply.	• High blood pressure / Hypertension • Diabetes • Heart Disease • High Cholesterol • Gastrointestinal Problems • Obesity • Cancer • Other ______________________ • None of the Above

Table 6.2: Nutrient Levels of Model Creamy Tomato Soup System

Nutrient Level	Sodium (milligrams)	Fat (grams)
Low	135	2.78
Reduced	435	5.56
Regular	735	8.33

Table 6.3: Ingredients for Model Creamy Tomato Soup System

Ingredients	Percentages (%)†
butter	1.35 - 4.05
Water	0 – 3.29
Milk, skim	31.5
Tomato sauce, no salt added	63.8
salt	0.07 - 0.66

†Percentages of butter, water, and salt varied with nutrient content level

Table 6.4: Soup Abbreviations

Nutrient Content of Soup	Abbreviation
Regular Fat	RF
Reduced Fat	DF
Low Fat	LF
Regular Sodium	RS
Reduced Sodium	DS
Low Sodium	LS
Regular Fat, Regular Sodium	RF-RS
Regular Fat, Reduced Sodium	RF-DS
Regular Fat, Low Sodium	RF-LS
Reduced Fat, Regular Sodium	DF-RS
Reduced Fat, Reduced Sodium	DF-DS
Reduced Fat, Low Sodium	DF-LS
Low Fat, Regular Sodium	LF-RS
Low Fat, Reduced Sodium	LF-DS
Low Fat, Low Sodium	LF-LS

Table 6.5: Comparison of Average Overall Liking of Creamy Tomato Soups in 1) Blind Tasting without Label, 2) Label Only and 3) Tasting with Label Conditions Rated on a 9-point Hedonic Scale

Overall liking in blind tasting condition without label	**Sodium**		
	Regular	Reduced	Low
	6.12a	6.05a	4.69b
	Fat		
	Regular	Reduced	Low
	5.74a	5.32b	5.36b
Expected overall liking in label only condition without tasting	**Sodium**		
	Regular	Reduced	Low
	5.67a	5.44ab	5.31b
	Fat		
	Regular	Reduced	Low
	5.8a	5.63ab	5.43b
Overall liking in tasting with label condition	**Sodium**		
	Regular	Reduced	Low
	6.07a	6.07a	4.77b
	Fat		
	Regular	Reduced	Low
	5.78a	5.7ab	5.43b

Means showing a common letter are not significantly different within each nutrient level (α= 0.05).

Table 6.6: Comparison of Average Overall Liking of Creamy Tomato Soups in 1) Blind Tasting without Label, 2) Label Only and 3) Tasting with Label Conditions Rated on a 9-point Hedonic scale Based on Sodium Level Nested within the Fat Level

Overall liking in blind tasting condition without label	Regular Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	6.25a	6.15a	4.99b
	Reduced Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	6.18a	6.15a	4.55b
	Low Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	5.93a	5.84a	4.52b
Expected overall liking in label only condition without tasting	Regular Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	5.97a	5.75a	5.52a
	Reduced Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	5.48a	5.22a	5.24a
	Low Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	5.55a	5.35a	5.16b
Overall liking in tasting with label condition	Regular Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	6.15a	6.2a	4.99b
	Reduced Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	6.13a	6.15a	4.83b
	Low Fat		
	Regular Sodium	Reduced Sodium	Low Sodium
	5.92a	5.88a	4.49b

Means showing a common letter are not significantly different within each sodium level nested within fat levels (α= 0.05).

Table 6.7: Comparison of Average Overall Liking of Creamy Tomato Soups in 1) Blind Tasting without Label, 2) Label Only and 3) Tasting with Label Conditions Rated on a 9-point Hedonic scale Based on Fat Level Nested within the Sodium Level

Overall liking in blind tasting condition without label	Regular Sodium		
	Regular Fat	Reduced Fat	Low Fat
	6.25a	6.18a	5.93a
	Reduced Sodium		
	Regular Fat	Reduced Fat	Low Fat
	6.15a	6.15a	5.84a
	Low Sodium		
	Regular Fat	Reduced Fat	Low Fat
	4.99a	4.55a	4.52a
Expected overall liking in label only condition without tasting	Regular Sodium		
	Regular Fat	Reduced Fat	Low Fat
	5.97a	5.48a	5.55a
	Reduced Sodium		
	Regular Fat	Reduced Fat	Low Fat
	5.75a	5.22a	5.36a
	Low Sodium		
	Regular Fat	Reduced Fat	Low Fat
	5.52a	5.24a	5.17a
Overall liking in tasting with label condition	Regular Sodium		
	Regular Fat	Reduced Fat	Low Fat
	6.15a	6.14a	5.92a
	Reduced Sodium		
	Regular Fat	Reduced Fat	Low Fat
	6.2a	6.15a	5.88a
	Low Sodium		
	Regular Fat	Reduced Fat	Low Fat
	4.99a	4.83a	4.49a

Means showing a common letter are not significantly different within each sodium level nested within fat levels (α= 0.05).

Figure 6.1: Sample Question from Expected Overall Liking with Labeling Information rated on a 9-point hedonic scale

Instructions: Rate the overall liking of the soup with the following label based on your **expected perceived** taste.

How would you rate your **overall liking** of the soup with the following label based on your **expected perceived** taste?

☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Figure 6.2: Verbal Label Used for Sorting Activity

Figure 6.3: Visual Label Used for Sorting Activity

Chapter 7: Threshold of Sodium in Model Reduced and Low Fat Oil-in-Water Emulsion Systems

7.1 Abstract

Sodium and fat reduction in food systems are key factors in the nutrition management of hypertensive individuals. Several reduced and lower fat food systems have higher amounts of sodium than their regular fat counterparts, which contradicts sodium and fat reduction goals for hypertensive individuals. The objective of this research was to measure the threshold of sodium in a model reduced and low fat oil-in-water emulsion system. Thirty panelists used the R-index by rating method to evaluate a model reduced fat emulsion system with 7 sodium concentrations (175 mg, 200 mg, 230 mg, 265 mg, 305 mg, 350 mg) increased by a factor of 1.15 and a model low fat emulsion system with 6 sodium concentrations (160 mg, 170 mg, 180 mg, 190 mg, 200 mg) increased by a factor of 1.06. Factors by which the levels were increased was based on preliminary testing. Panelists received 10 replicates of noise and signal samples for both fat levels. The group threshold for the reduced and low fat emulsions were 241.11 mg and 183.56 mg, respectively. Results indicate saltiness perception is increased when fat content is decreased, and threshold for sodium in the reduced fat emulsion system is higher than the low fat emulsion system with lower fat content. Study findings show opportunities for sodium reduction in reduced and low fat food emulsion systems, particular additional reductions of sodium without consumer detection.

Practical Application: Study results demonstrated that sodium difference thresholds for the reduced and low fat emulsions were at levels lower than the average sodium content found in comparable processed food systems, including salad dressing. Results indicate that sodium content can be decreased in reduced and lower fat food emulsion systems without consumer detection. With the majority of hypertensive individuals requiring reductions of both sodium and fat in food systems, food products which offer reduced and low fat options also need reduced levels of sodium. Having insight for where consumers are able to detect a difference in sodium levels within reduced and low fat food systems can contribute to a successful reduction of sodium in reduced and lower fat food systems.

Keywords: sodium, fat, emulsion, R-index, threshold

7.2 Introduction

Elevated sodium consumption has consequently been associated with increased numbers of hypertensive adults in the United States (U.S.) (Go and others, 2013). With over 70% of hypertensive adults in the U.S. being overweight or obese (Whelton and others, 2002), approaches for both sodium and fat reduction in processed food systems are being examined.

The primary source of dietary sodium consumption in the U.S. comes from processed foods (CDC, 2012). A study which examined the relationship between sodium and fat content in ten processed food categories determined that sodium content is significantly higher in reduced and lower fat versions versus the full fat counterpart in several categories (Cox and others, 2015). Salad dressings, an oil-in-water emulsion system, was one of the categories that demonstrated an inverse relationship between sodium and fat levels, such that in reduced and lower fat salad dressings, sodium content was elevated compared to the full fat products. Increased sodium in reduced and lower fat processed food systems could compensate for the reduction in fat by serving as an enhancer to the taste of the food system.

Research conducted on the correlation between fat content and saltiness perception in oil-in-water emulsion systems have produced varying conclusions. Past studies examining oil-in-water emulsions determined that saltiness perception decreased with a corresponding decrease in fat content (Yamamoto and others, 1999; Malone and others, 2003; Suzuki and others, 2010). In addition, the studies concluded that, with sodium being dispersed in the aqueous phase, an increase in both fat and sodium content corresponded to an increase in saltiness perception. However, when the sodium concentration was kept constant and the fat content was increased, studies concluded that saltiness perception decreased due to reduced contact of sodium to the taste receptor cells (Yamamoto and others, 1999). However, in another investigation of oil-in-water emulsions, it was found that fat had no effect on saltiness intensity even when sodium concentration differences in the aqueous phase were adjusted (Metcalf and others, 2002). Yet another study concluded that saltiness perception is influenced by the total concentration of sodium in the emulsion, and noted that fat may have additional effects on saltiness perception (Suzuki and others, 2014).

Conducting threshold testing on oil-in-water emulsion systems provides insight into levels at which consumers are able to detect a difference in sodium content at varying fat levels. By obtaining threshold values, one can then make estimates of how much sodium is needed for consumer detection in reduced and lower fat food systems, and can play a significant part in product formulation. The R-index measure by rating method of threshold testing was initially applied to examine threshold levels for sodium and sucrose (McFadden and others, 1971; O'Mahony, 1972). It has since been applied to a variety of food applications in which consumer detection of a difference impacts acceptance, including caffeine and soy isoflavones (Robinson and others, 2004; Robinson and others, 2005).

The overall goal of this study was to identify optimum levels of sodium and fat reduction for processed food systems.. In order to obtain this goal, the objective of this research was to measure the threshold of sodium in a model reduced and low fat oil-in-water emulsion system. It was hypothesized that threshold of sodium will be affected by the fat content in a model emulsion system. We further hypothesized that as fat content is increased sodium is less detectable in the model emulsion system.

7.3 Materials and Methods

7.3.1 Samples

A reduced fat emulsion system with 7 sodium levels (Table 7.1), and a low fat emulsion with 6 sodium levels (Table 7.2) were prepared for threshold testing. The emulsion formulation consisted of the following ingredients: distilled water, soy lecithin (Solec WD, The Solae Company, St. Louis, MO, U.S.A.), Crisco Pure Vegetable Oil (The J.M. Smucker Company, Orrville, OH, U.S.A.), sodium chloride (Morton Salt, Inc., Chicago, IL, U.S.A.), and xanthan gum (NovaXan D; Archer Daniels Midland, Decatur, IL, U.S.A.).

The emulsions were prepared in 600 g batches using a Vitamix TurboBlend Two Speed blender (Cleveland, Ohio, U.S.A.). High speed for the blender was 25,300 rotations per minute (rpm) for low speed and 28,900 rpm for high speed. Emulsion formulation steps were: 1) weigh out all ingredients, 2) add distilled water to soy lecithin, 3) blend soy lecithin and distilled water on high speed for 10 seconds, 4) add 50% of the oil to the blender carafe, 5) add the remaining 50% of the oil to the carafe during blending at low speed for 60 seconds, 6) add NaCl and xanthan gum to the carafe, 7) blend emulsion on high speed for 1 minute, and 8) refrigerate mixture at 2°C.

The fat content of the reduced and low fat emulsions was based on nutrition information of salad dressings previously collected in a grocery inventory study (Cox and others, 2015). Study findings from the grocery inventory indicated the mean fat content for regular fat salad dressings was 11 g/serving based on a 30 g/serving size. The reduced-fat emulsion system contained 9 grams of fat per 30 g/serving (Table 7.3), meeting the Food and Drug Administration reduced fat claim definition of ≥ 25% reduction in fat (FDA, 2013). The low fat emulsion contained 3 g of fat per 30 g/serving (Table 7.4).

The sodium content of the reduced and low fat emulsions were based on preliminary testing for difference threshold. A total of 10 panelists participated in preliminary testing. Four preliminary tests were conducted for the reduced fat emulsions, and three preliminary tests were conducted for the low fat emulsions. Sodium levels selected for preliminary testing were based on the mean sodium content of ranch salad dressings from nutrition labels collected in a grocery inventory study. The mean sodium content of regular fat ranch salad dressing was 270 mg/serving, and the mean sodium content of reduced fat ranch salad dressing was 330 mg/serving. Preliminary testing for difference threshold for the reduced and low fat emulsions were conducted with sodium levels between 175 - 450 mg/serving (Appendices H, I, and J) and 160 mg and 350 mg/serving (Appendices K and L), respectively.

The reduced and low fat emulsions contained seven (175 mg, 200 mg, 230 mg, 265 mg, 305 mg, 350 mg) and six (160 mg, 170 mg, 180 mg, 190 mg, 200 mg) levels of sodium content, respectively. Sodium levels for the reduced fat emulsions were increased by a factor of 1.15, and 1.06 for the low fat emulsions, in order to meet levels established from preliminary testing. The factors, in which sodium levels for the reduced and low fat emulsions were increased, were based on the control sample (150 mg).

The control sample or noise was determined to be a sodium content of 150 mg/serving for both the reduced and lower fat emulsion systems. The sodium content of the noise was determined to be below the difference threshold for both the reduced and low fat emulsion systems, which allowed for comparison between the two systems.

The emulsions were stored in airtight food grade storage containers (Snapware Coproration, Mira Loma, CA, U.S.A.) for the 5 day testing period. Samples for testing were placed in 60 mL capacity clear plastic cups with lids (Solo Cup Co., Urbana, IL, U.S.A.). Samples and containers were stored in a refrigerator with an internal temperature of 5°C. Samples were removed from the refrigerator one hour prior to testing each day, and were served at room temperature (22°C). No changes in pH or viscosity were noted in the emulsions over the 5 days of testing (Appendices M and N).

7.3.2 Subjects

A total of 30 panelists were recruited to participate in the study, which is consistent with prior threshold testing studies (Robinson and others, 2004; Robinson and others, 2005; Kappes and others, 2006). Twenty-five panelists were female, and five were male. Age range of the panelists ranged from 26-49 years of age. Eleven panelists were Caucasian, one was African American, 5 were Hispanic or Latino, 12 were Asian, and 1 selected other for ethnicity. Panelists were recruited through e-mail listserv through the University of Illinois (Appendix O). Panelists completed a screening questionnaire (Appendix P) and were tested for taste acuity (Appendix Q) before being selected to participate in testing.

7.3.3 Procedure

Sensory threshold can be measured by the signal detection rating method using the R-index measure. In the signal detection rating method using the R-index measure, a panelist is asked to differentiate between a signal (test) or noise sample (Brown, 1974). The panelist selects whether the sample is the signal or noise based on how sure their choice is, and can select from the categories of signal sure, signal unsure, noise sure, and noise unsure. The R-index measure by rating method quantifies the degree of difference between the noise and the test samples. The signal detection rating method using the R-index measure was adapted by O'Mahony for sensory analysis of food applications, with an initial focus on examining sodium threshold levels (O'Mahony, 1972). The R-index by rating method presents all replicates in one session and uses fewer samples as opposed to other threshold testing methods (Robinson and others, 2004; Robinson and others, 2005; Kappes and others, 2006).

A total of 10 sessions were conducted for threshold testing of the reduced and low fat emulsions over a two week period. A total of five sessions were conducted for the reduced fat emulsions during the first week with one session per day. The same experimental protocol was followed for the low fat emulsions during the second week. Two replications of the emulsion samples were presented to the panelists during each session.

The emulsion samples along with the noise (control) sample were presented to the panelists in 60-mL capacity clear plastic cups that were labeled with 3-digit codes. Panelists were asked to become familiar with the noise sample. Panelists were, then, instructed to place a teaspoon of each sample into the mouth, leave it on the tongue for 5 seconds, and expectorate. Panelists were asked if the sample was a signal sure, signal unsure, noise sure, or noise unsure (Appendix R). Panelists were required to rinse prior to and during testing in between each sample with bread (Sara Lee, Inc., Soft and Smooth, Chicago, IL, U.S.A.), carbonated water (Meijer, Inc., Grand Rapids, MI, U.S.A.), warm purified water, and room temperature distilled water. Samples were presented monadically.

Testing was conducted in a booth setting with a controlled temperature of 22°C and 33% relative humidity. The samples were evaluated under incandescent lighting. Each session was approximately 30 minutes in length. A randomized complete block was used for ten replications of seven concentration levels and the noise for the reduced fat samples, and for ten replications of five concentration levels and the noise for the low fat samples. Data collection and sample randomization was done through the Compusense *five* Plus (Version 5.0: Guelph, Ontario, Canada) data acquisition program.

7.3.4 Statistical Analysis

Threshold was determined through the R-index measure. The R-index measure is based on the response matrix for each panelist when evaluating the emulsion samples to determine if the sample is a signal or noise (Table 7.5). The R-index equation (Equation 1) is used to determine the R-index measure, which is represented by percentage. The denominator is the total number of signal samples presented multiplied by the total number of noise samples presented during the test (O'Mahony, 1992):

$$R = \frac{a(f+g+h)+b(g+h)+c(h)+\frac{1}{2}(ae+bf+cg+dh)}{n_s n_n} x100 \qquad \text{(Equation 1)}$$

For both the reduced and low fat samples, 10 samples of each noise and signal sample were evaluated. The R-index of the reduced and low fat samples from each panelist was calculated from the R-index equation. From the R-index measures, sodium threshold values were plotted as a function of R-index percentage for each panelist (Figure 7.1). A linear trendline was constructed between the 2 points that were both directly above and below the R-index value of 75%. From the linear equation, the sodium threshold (x-value) was extrapolated for the R-index (y-value) of 75%. The empirical threshold is defined as the level where correct discrimination from a blank stimulus occurs at 50% above the chance level of performance (ASTM E 1432, 2002). For the signal detection method utilizing the R-index measure, an R-index of 50% would indicate chance level of correctly identifying a signal as a signal or a noise as a noise and 100% would indicate perfect discrimination. The empirical threshold occurs at the R-index value of 75%, which is 50% more than chance performance (O'Mahoney, 1992). The group average threshold was calculated by compiling the individual threshold values and obtaining an average.

The pooled threshold, was calculated by compiling all panelist responses, calculating the R-index value, and extrapolating the threshold value.

7.4 Results and Discussion

Table 7.6 lists the individual and group average thresholds for sodium extrapolated from the R-index of 75% for the reduced and low fat emulsions. The group average threshold for sodium was 241.11 mg sodium/30 g sample for the reduced fat samples. The pooled threshold, which was extrapolated from the pooled R-index calculations of the sodium levels tested (Table 7.7), was 255.77 mg sodium/30 g sample. The thresholds for individual panelists ranged from 170.83 mg sodium/30 g sample to 308.34 mg sodium/30 g sample. Nineteen panelists' thresholds were within the range from 200-275 mg sodium/30 g sample, close to the group average threshold as shown in Figure 7.2.

The group average threshold for sodium was 183.56 mg sodium/30 g sample for the low fat samples. The pooled threshold, which was extrapolated from the pooled R-index calculations of the sodium levels tested (Table 7.8) was 188.75 mg sodium/30 g sample. The thresholds for individual panelists ranged from 156.41 mg sodium/30 g sample to 199.28 mg sodium/30 g sample. Twelve panelists' thresholds were within the range from 181-190 mg sodium/30 g sample close to the group average threshold as shown in Figure 7.3.

Our findings support that sodium detection is decreased as fat content is increased in the emulsion system. The research debate regarding the effect of fat content on saltiness perception involves several factors. The studies that support our findings of increased fat content inhibiting saltiness perception explains the phenomenon in a few different ways. Since fat is hydrophobic in nature, it can act as a barrier against sodium migration and prevent the release of sodium from a food matrix (Hughes and others, 1997). In addition, fat can also delay contact of sodium to the taste buds by coating the surface of the tongue (Lynch and others, 1993). However, contrary to our findings, a few studies have shown that certain components of fat may sensitize taste receptor cells, which can result in an increase in saltiness perception (Gilbertson and others, 2005; Mattes, 2009).

The findings of our study are limited to the oil-in-water emulsion system that was tested. Though our study results demonstrated that threshold was increased in a higher fat system, research has shown taste perception in foods can be significantly modified by other ingredients in more complex model food systems (Laurila and others, 1996). The more complex the food is, the less possible it may be to differentiate between levels of sodium. When detection between sodium levels in distilled water and in canned, unsalted tomato juice were compared, taste and flavoring component of the tomato juice were found to interfere with detection of sodium versus the distilled water (Pangborn and others, 1982). Sodium has also been found to decrease perception of sourness and bitterness, and complex food systems which carries these other tastes could be impacted by changes in sodium levels (Pangborn and others, 1964). Other components, including fat level, water content, and content of additional nutrients such as proteins, have an impact on perception of saltiness. Additionally, many studies have only investigated specific aspects of saltiness perception without considering all product components, such as how the sodium is released from the product, and how the sodium is available in the mouth to be perceived (Kuo and others, 2014). Oil-in-water emulsions that are more complex could influence saltiness perception depending on the attributes of the emulsion.

Panelists also completed a questionnaire regarding dietary intake of sodium and fat and concern of sodium and fat intake (Appendix S). Of the 30 panelists, no one had hypertension or pre-hypertension. Fifteen of the panelists reported having a family history of hypertension, and fifteen of the panelists did not. Eight of thirty panelists reported having a family history of pre-hypertension.

When asked about their daily sodium consumption, twelve panelists reported a daily sodium consumption of more than 4800 mg, which is more than double the amount of the recommended intake of less than 2300 mg (USDA, 2010). When asked about daily fat intake, 17 of the 30 panelists reported a daily consumption of 65 grams, which is the recommended intake (USDA, 2010). When asked about concern of sodium in daily food intake, twenty panelists reported that they were somewhat concerned. When asked about concern of fat in daily food intake, nineteen panelists reported that they were somewhat concerned. When asked about importance of sodium content when purchasing a food product, fifteen panelists reported that they were somewhat concerned. When asked about importance of fat content when purchasing a food product, seventeen panelists reported that they were very concerned.

From the survey findings, panelists report consuming more sodium than the recommended intake, and are not highly concerned about consumption. However, panelists reported consuming the recommended intake of fat, though they are not highly concerned about fat consumption as well. With panelists reporting a higher sodium consumption than fat consumption, determining sodium threshold levels in food products may be a factor in reducing a nutrient that may not be of importance to some consumers.

7.5 Conclusions

The reduction of dietary sodium in food products plays a significant impact on consumer acceptance of reduced and lower fat food products. Recommended strategies from the Institute of Medicine to reduce sodium content in food products have included a gradual and stealth reduction. Understanding the threshold of sodium in reduced or lower fat emulsion systems, such as salad dressings, could assist in a stealth reduction in these products, while maintaining consumer acceptance.

As demonstrated in the study findings, fat content may impact detection of sodium by providing a compensation effect, in which levels of one nutrient is increased due to decreased levels of another nutrient in order to maintain consumer acceptance. With the increase in overweight or obese individuals, the effect of lipid content on taste perception is important for the development of reduced and low fat food systems, specifically food emulsions systems.

Findings from this study could assist in developing mechanisms to reduce sodium levels in specific oil-in-water emulsion systems. Understanding the threshold of sodium levels in reduced and lower fat emulsion systems can be extrapolated to reducing sodium levels in reduced and lower fat emulsion-based food products. Additional research to examine sensory acceptance of the emulsion system would assist in understanding if consumers would accept the sensory properties of the system where the threshold was detected. Because saltiness perception is influenced by other factors in food products, such as flavorings, further research needs to be conducted on sodium threshold in complex reduced and lower fat emulsion systems such as salad dressings and soups.

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7.7 Tables and Figures

Table 7.1: Formulation for Reduced Fat Emulsions
(Sodium content increased by factor of 1.15)

Ingredients (%wt/wt))	Sodium Quantity (mg)[†]						
	150mg	175mg	200mg	230mg	265mg	305mg	350mg
Oil	30	30	30	30	30	30	30
Water	67.43	67.22	67.00	66.75	66.46	66.37	66.15
NaCl	1.27	1.48	1.70	1.95	2.24	2.33	2.55
Xanthan Gum	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Soy Lecithin	0.5	0.5	0.5	0.5	0.5	0.5	0.5

[†] Sodium quantity is based on 30g sample basis.

Table 7.2: Formulation for Low Fat Emulsions
(Sodium content increased by factor of 1.06)

Ingredients (%wt/wt)	Sodium Quantity (mg)[†]					
	150mg	160mg	170mg	180mg	190mg	200mg
Oil	10	10	10	10	10	10
Water	87.43	87.35	87.26	87.18	87.09	87.00
NaCl	1.27	1.35	1.44	1.52	1.61	1.70
Xanthan Gum	0.8	0.8	0.8	0.8	0.8	0.8
Soy Lecithin	0.5	0.5	0.5	0.5	0.5	0.5

[†] Sodium quantity is based on 30g sample basis.

Table 7.3: Nutrition Information for Reduced Fat Emulsions

Serving Size (grams)	30 grams
Total Calories[†] (kcal)	77
Calories from Fat (kcal)	76.85
Fat (grams)	8.5

[†] Xanthan gum accounts for 0.15kcal

Table 7.4: Nutrition Information for Low Fat Emulsions

Serving Size (grams)	30 grams
Calories (kcal)	26
Calories from Fat (kcal)	26
Fat (grams)	2.89

Table 7.5: Example response matrix for one panelist who evaluated reduced fat emulsion samples using the R-index measure

	Signal Sure	Signal Unsure	Noise Unsure	Noise Sure
Signal (350 mg)	2	0	0	0
Signal (305 mg)	1	1	0	0
Signal (265 mg)	0	1	1	0
Signal (230 mg)	0	1	0	1
Signal (200 mg)	0	0	2	0
Signal (175 mg)	0	0	1	1
Noise (150 mg)	0	0	1	1

Table 7.6: Difference Threshold values for 30 panelists by the R-index measure of 75%

Panelist	Reduced Fat (mg sodium /30g sample)	Low Fat (mg sodium /30g sample)
1	214.73	188.80
2	209.21	195.65
3	174.04	187.78
4	261.00	185.29
5	263.00	157.04
6	280.10	168.40
7	219.19	196.00
8	175.00	168.43
9	216.17	183.68
10	230.00	184.04
11	170.83	193.89
12	277.50	185.45
13	247.40	195.45
14	219.13	184.00
15	300.00	176.82
16	189.29	169.66
17	ND	ND
18	263.66	180.00
19	263.02	190.00
20	ND	156.85
21	242.34	197.69
22	252.49	189.39
23	245.50	197.50
24	230.00	199.38
25	268.90	198.00
26	260.56	ND
27	296.82	187.33
28	308.34	184.64
29	262.06	156.41
30	210.88	182.12
Mean	241.11	183.56
Standard Deviation	37.09	12.55

ND = Not detected

Table 7.7: Pooled R-Index Values for Reduced-Fat Emulsions[†]

Na/serving (mg)	**Pooled R-Index (%)**[††]
175	54.88
200	59.41
230	69.10
265	76.84
305	80.52
350	83.73

[†] Testing had 10 replications for each panelist. So, the total replication to calculate pooled R-index was 300 (10 reps × 30 panelists) for each sample concentration.
[††] Pooled R-Index value for each sodium level obtained by compiling all panelist matrix responses and calculating the R-index value

Table 7.8: Pooled R-Index Values for Low Fat Emulsions[†]

Na/serving (mg)	Pooled R-Index (%)[††]
160	58.86
170	61.90
180	68.08
190	75.85
200	77.22

[†] Testing had 10 replications for each panelist. So, the total replication to calculate pooled R-index was 300 (10 reps × 30 panelists) for each sample concentration.

[††] Pooled R-Index value for each sodium level calculated by compiling all panelist matrix responses and calculating the R-index value (Equation 1)

Figure 7.1: Graph representing one panelist's R-index measure for each sodium concentration tested and linear trendline equation for R-index data point of 75% for reduced fat emulsion system

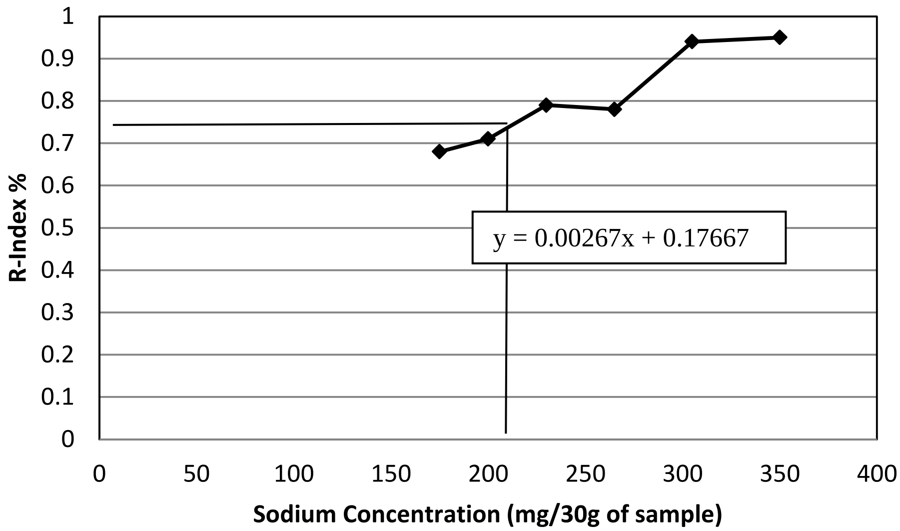
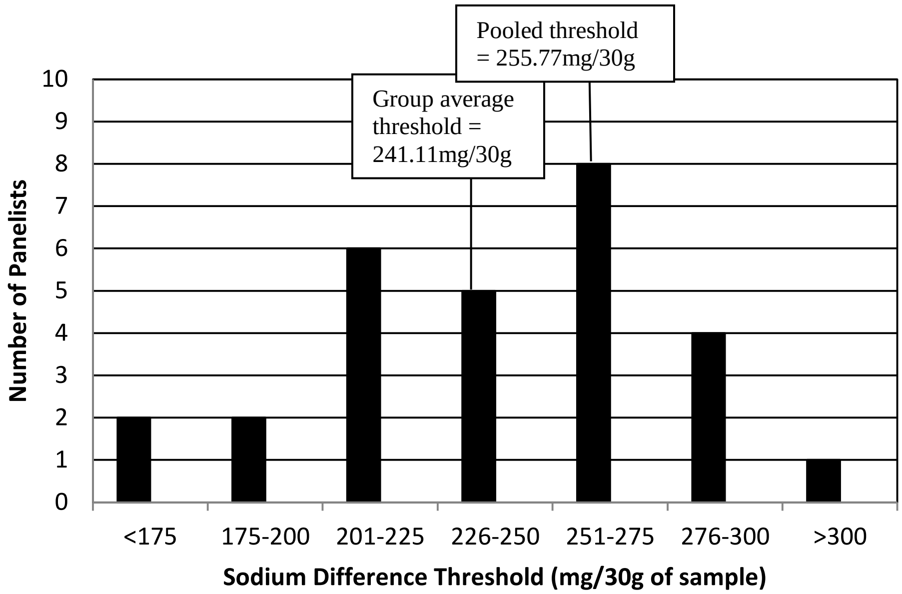
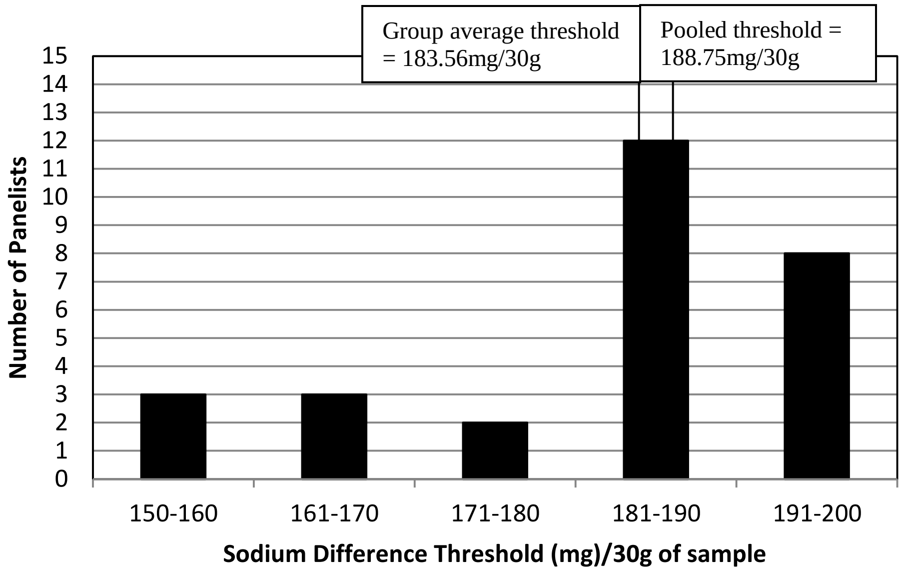


Figure 7.2: Distribution of difference thresholds for 30 panelists measured by 10 replicates of the R-index by rating method for reduced fat emulsions†



† Group Average R-Index for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average.
†† Pooled R-Index value for each sodium level calculated by compiling all panelist matrix responses and calculating the R-index value.

Figure 7.3: Distribution of difference thresholds for 30 panelists measured by 10 replicates of the R-index by rating method for low fat emulsions†



† Group Average R-Index for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average.
†† Pooled R-Index value for each sodium level calculated by compiling all panelist matrix responses and calculating the R-index value.

Chapter 8: Conclusions and Future Directions

Approaches to sodium reduction in processed food systems include decreasing dietary consumption of both sodium and fat. The grocery inventory study found that several processed food categories had an inverse relationship between sodium and fat content, and sodium was higher in the reduced or lower fat food system versus the regular counterpart Findings for the grocery inventory are limited to the data collected at the time of the study.

The nutrient claims study surveyed knowledge of sodium and fat nutrient content claims for consumers and health and food professionals, and concluded that all groups were not knowledgeable on nutrient content claims for sodium and fat. Survey results indicate that there is room for increased comprehension of nutrient content claims and recommended dietary intake by consumers and health and food professionals. With the survey being conducted online, no proof of the validity of occupational category selected is available. The survey not being tested for reliability was an additional study limitation.

When examining drivers of liking in a model retorted tomato soup system, increased levels of sodium when fat was decreased resulted in a compensation effect which impacted consumer acceptance and increased overall liking. The compensation effect was enhanced with the addition of herbs, which also increased overall liking Results implied that the compensation effect between sodium and fat could increase consumer acceptance in lower sodium and fat food products. Descriptive analysis for the tomato soup system noted specific attributes contributed to an increase or decline in overall liking from consumer testing. Results implied that attributes contributing towards decreased overall liking could be reformulated to increase consumer acceptance. Study limitations included potential palate fatigue, the influence of temperature variation of the soups on taste perception, and that interpretation of study results are limited to soup systems.

Additional testing with the model retorted tomato soup system showed that front-of-package labeling had no impact on consumer acceptance when presented with the sample versus when the sample was presented in a blind fashion. Study results imply there could be increased consumer acceptance of lower sodium and fat foods even when provided with labeling information. Study limitations correspond to those from the drivers of liking study.

Findings from this sodium threshold study demonstrated that sodium levels in reduced and low fat emulsions could be reduced without consumer detection. Study limitations include palate fatigue, and findings are limited to oil-in-water emulsion systems. Determining threshold levels for sodium in reduced and low fat emulsion systems can be extrapolated to reducing sodium levels in reduced and low fat emulsion-based food products.

Future directions regarding the compensation effect between sodium and fat in processed food systems and its impact on sensory applications could include several pathways. Because consumers and heath and food professionals are not fully knowledgeable on nutrient content claims pertaining to sodium and fat, the impact of nutrition education should be assessed to examine whether increased nutrition knowledge impacts the selection of processed food products by consumers. Consumers could be assessed for nutrient content claims knowledge through online modules along with quizzes for verification of content. After the completion of the modules, consumers could be presented with a variety of food products with and without nutrient content claims in order to assess if nutrition education impacts the selection of processed food products. Comparisons of nutrition education programs and their effectiveness could also be determined.

With medical professionals having the least knowledge of nutrient content claims, additional nutrition education could be provided in medical curricula. With Registered Dietitians having the highest knowledge of nutrient content claims, they could serve as providers of nutrition education for medical professionals. Effectiveness of nutrition education through Registered Dietitians would have to be assessed. The influence of additional nutrition education for medical professionals on enhancing the nutrition education of consumers would also have to be assessed.

Though the drivers of liking study focused on one model retorted food system, future research could focus on expanding current findings to other similarly processed food systems. Descriptive analysis and consumer testing could be conducted on other soup types and variations to determine what attributes contribute towards increased or decreased overall liking. Because labeling versus no labeling did not impact consumer acceptability of the tomato soup, further research can be conducted to see if consumers would choose lower sodium and fat soups when labeling information is provided. This research can be extended to other processed food products which demonstrate a compensation effect.

Findings from the sodium threshold study, which focused on a model emulsion system, can be applied to other oil-in-water food emulsion systems in which sodium levels are compensated for fat, such as ranch and Italian salad dressings. Determining sodium threshold levels in these food systems could assist in the IOM’s recommendation for a stealth reduction of sodium in processed food systems. Additionally, further research, including descriptive analysis, would be needed to examine sensory acceptance of the emulsion systems at the established threshold levels.

Appendices

Appendix A: Template for Nutrition Data Collection for Grocery Inventory Study

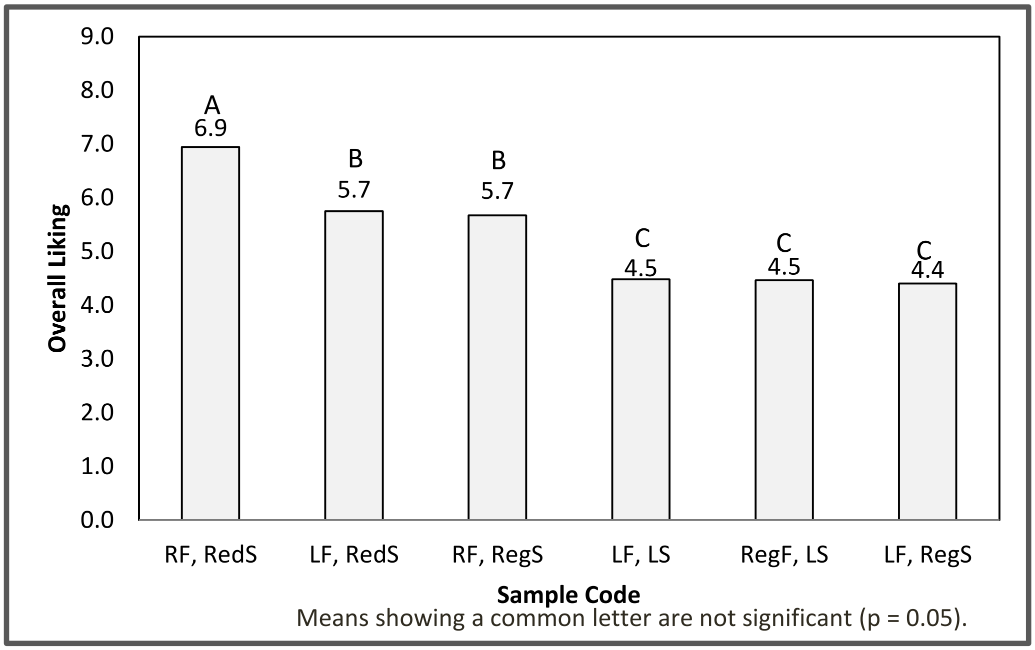
Research Assistant Name: ____
Time/Date: ____
Food Category: ____
Grocery Store: ____
Address: ____

Brand/Flavor	
Claim (ex. 25% less sodium)	
Specifics of Claim (ex. 480mg sodium vs. 890 mg for regular product)	
Serving Size	
Number of Servings	
Total Calories	
Calories from Fat	
Total Fat (g)	
Saturated Fat (g)	
Polyunsaturated Fat (g)	
Monounsaturated fat (g)	
Cholesterol (mg)	
Sodium (mg)	
Potassium (mg)	
Total Carbohydrate (g)	
Fiber (g)	
Sugars (g)	
Protein (g)	

Appendix B: Description of Preliminary Testing of Fresh Creamy Tomato Soups

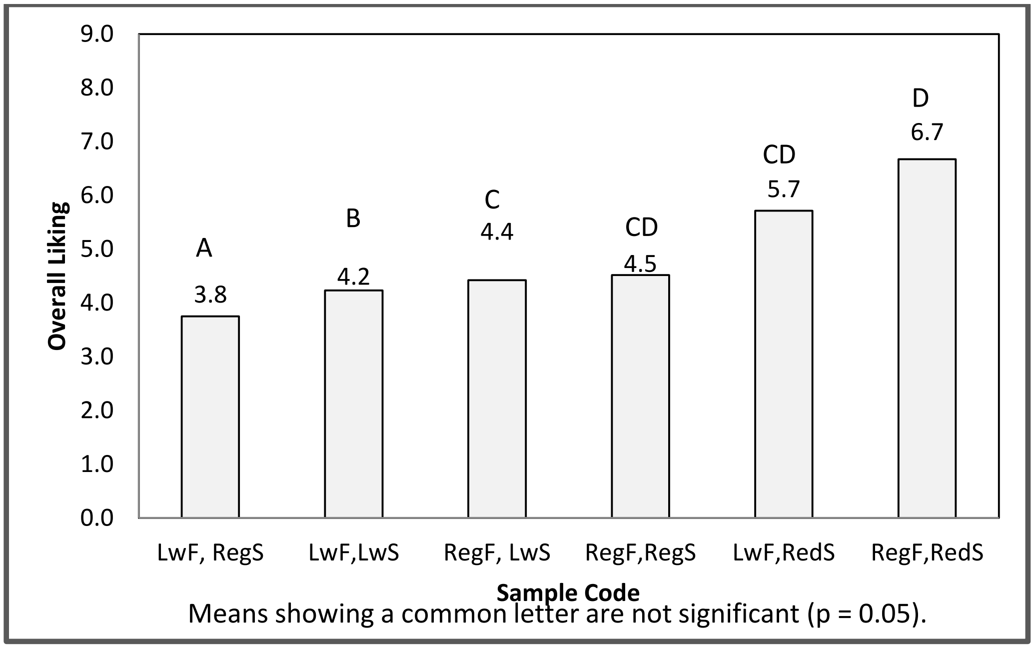
In order to examine overall liking in a model soup system, a model fresh creamy tomato soup consumer test was conducted. Six fresh creamy tomato soups were developed with three levels of sodium (low sodium, reduced sodium, regular sodium) and two levels of fat (low fat, regular fat). Fifty two consumers participated in the consumer test. Consumers were asked to evaluate for overall liking and on attributes of appearance, aroma, mouth feel, taste, saltiness, and fat level. A 9-point hedonic scale was used, ranging from 1 to be equal to "dislike extremely" and 9 being "like extremely". The regular fat, reduced sodium sample had the highest ranking for overall liking (Figure 5), and there was a significant statistical difference ($p = 0.05$) in overall liking between the regular fat, reduced sodium sample versus all other samples. The regular fat, reduced sodium sample had the highest ranking for saltiness liking (Figure 6), and there was a significant statistical difference in saltiness liking between the regular fat, reduced sodium sample versus the other samples (except for the low fat, reduced sodium sample). Additionally, the regular fat, reduced sodium sample had the highest ranking for fat level liking (Figure 7), and there was a significant statistical difference in fat level liking between the regular fat, reduced sodium sample versus the other samples (except for the regular fat, regular sodium sample).

Appendix C: Overall Liking of Fresh Creamy Tomato Soups



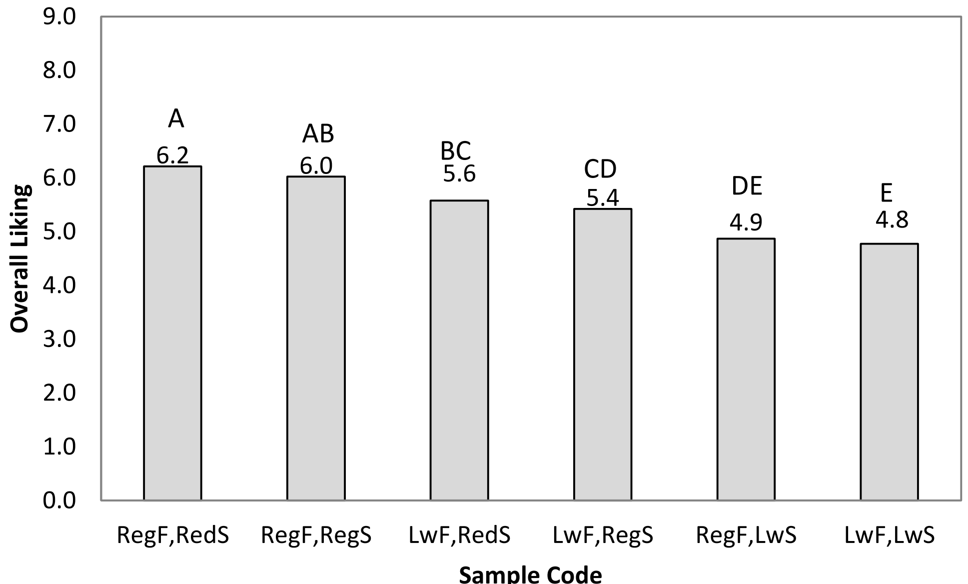
Factors	Nutrient Levels
F = Fat	Reg = Regular
S = Sodium	Red = Reduced
	Lw = Low

Appendix D: Saltiness Liking of Fresh Creamy Tomato Soups



Factors	Nutrient Levels
F = Fat	Reg = Regular
S = Sodium	Red = Reduced
	Lw = Low

Appendix E: Fat Liking of Fresh Creamy Tomato Soups



Means showing a common letter are not significant (p=0.05).

Factors	Nutrient Levels
F = Fat	Reg = Regular
S = Sodium	Red = Reduced
	Lw = Low

Appendix F: Taste Identification Questionnaire for Descriptive Analysis Study

Name: ________________________________ Date: _________

SOLUTION TESTS

Your task is to recognize the basic taste of each sample solution (sweet, salty, sour, bitter, or umami). Write in the blank which taste you perceive. When the sample tastes like water mark with a "0". If your recognition is questionable, write a question mark "?". Retasting is allowed.

For each sample, take the sample into the mouth in sips and move it around in such a way that it touches all parts of the tongue. Do not swallow the sample; use spit cups. Rinse between samples with spring water.

Sample Codes	Basic Taste
976	umami (MSG solution 0.5 g/L)
740	blank (distilled water)
439	sweet (sucrose solution 20 g/L)
300	salty (NaCl solution 0.8 g/L)
143	bitter (caffeine solution 0.7 g/L)
279	sour (citric acid solution 0.6 g/L)

PAPER TEST

Place the piece of filter paper on your tongue, close your mouth, and wet the paper with saliva for 10 seconds.

Do you perceive a taste? ______________________

If so, what do you taste? ______________________

On a scale of 1-10 (ten being the strongest possible taste), circle the number that represents how strong the taste you perceive is (if you didn't perceive anything, leave this blank).

1 Very weak
2
3
4
5
6
7
8
9
10 Very Strong

Appendix G: Summary of Descriptive Analysis Study

Day 1 Introductory Session/Soup Sample Attribute Generation A sign in sheet was distributed and name tags were provided. Panel leader introduced herself, and panelists introduced themselves. Panelists read and signed informed consent form, and completed form regarding panelists' personal contact information for payment purposes. Panelists were introduced to basic sensory science practices and DA methodology. Panelists were introduced to modalities (appearance, aroma, aroma-by-mouth, taste, texture, aftertaste), from which attributes would be generated for the modalities. Panelists were provided with a 15 mL soup sample, and were asked to generate attributes to the sensory modalities. Panelists were then provided with 5, 15 mL soup samples, and were asked to generate attributes to the sensory modalities. Term generation forms for attributes by the panelists were compiled for review.
Day 2-4 Soup Sample Attribute and Reference Generation A sign in sheet was distributed and name tags were provided. Panelists were reintroduced to modalities (appearance, aroma, aroma-by-mouth, taste, texture, aftertaste), from which attributes would be generated for the modalities. Panelists were provided with 6, 15 mL soup samples and suggested references, and were asked to generate attributes to the sensory modalities. Definitions for the attributes were discussed, and references for the attributes were suggested. Term generation forms for attributes and references by the panelists were compiled for review.
Days 5-6 Soup Sample Attribute Finalization and Reference Generation A sign in sheet was distributed and name tags were provided. Panelists were reintroduced to modalities (appearance, aroma, aroma-by-mouth, taste, texture, aftertaste), from which attributes would be generated for the modalities. Panelists were provided with 6, 15 mL soup samples and suggested references. Panelists were also provided with the compiled list of attributes, definitions of the attributes, and references. Panelists were provided time to review the attributes generated, provide definitions of attributes that would remain on the list, and to decide if new attributes needed to be added or if any attributes needed to be removed from the list. Panelists were also asked to decide if the references provided matched the attribute in both modality and concentration. Panelists then held a group discussion to discuss any attributes that should be removed from the list, references that should be removed from the list, and any additional references that should be included in the list. Attributes (18 total) and attribute definitions were finalized.
Day 7 Reference Finalization A sign in sheet was distributed and name tags were provided. Panelists were provided with 6, 15 mL soup samples and suggested references. Panelists were also provided with the compiled list of attributes, definitions of the attributes, and references. Panelists were provided time to review references and decide if the references match the attribute in both modality and concentration. Panelists then held a group discussion to discuss the finalizing of references (references that should be removed from the list, any additional references that should be included in the list).

Appendix G (continued)

Day 8 Finalization of References and Introduction to Reference Rating A sign in sheet was distributed and name tags were provided. Panelists were provided with 6, 15 mL soup samples and suggested references. Panelists were also provided with the compiled list of attributes, definitions of the attributes, and references. Panelists were provided time to review references and decide if the references match the attribute in both modality and concentration. Panelists then held a group discussion to discuss the finalizing of references (references that should be removed from the list, any additional references that should be included in the list). Panelists were provided with a brief introduction to reference rating.
Days 9-12 Reference Rating/Finalization of Reference Intensity Values/Soup Sample Rating Practice A sign in sheet was distributed and name tags were provided. Panelists were provided with six 15 mL soup samples and samples of references that were finalized. Panelists were also provided with the compiled list of attributes, definitions of the attributes, and references. Panelists were reintroduced to reference rating. Panelists were provided with reference rating forms, and were given time to assign each reference a value on a 0-15 point scale indicating its intensity compared to the perceived intensity of the attribute in the sample set. There was then a group discussion on reference ratings. Ratings were combined with the previous session and averaged to determine final placement of references on the category scale. Once reference intensity values were finalized, panelists were presented with rating sheets that included references along with a numerical value for the intensity of the references. Panelists were then given time to rate each soup sample for all 18 attributes using the attribute reference as an anchor for intensity. Panelists then discussed as a group the sample ratings.
Days 13-14 Booth Practice Ratings for Soup Samples Panelists participated in two 30-minute practice testing sessions of 6 soup samples to become familiar with the booth setting and Compusense software. Panelists were provided with individual and group ratings from the sample rating practice sessions in order to compare their individual performance to the panel as a whole.
Days 15-22 Booth Testing for Soup Samples Panelists participated in one 30-minute evaluation of 6 soup samples. Data were collected using Compusense software. Panelists received their samples in individual booths with a controlled temperature of 22°C with 50% relative humidity and black lightning inside each booth to minimize appearance of color within soups. Rinse protocol between soup samples was carbonated water (Meijer, Inc., Grand Rapids, MI, USA), warm distilled water, and room temperature distilled water.

Appendix H: Preliminary R-Index Results of Reduced Fat Model Emulsions (Test One)†

Sodium Content	Group Average R-Index††	Pooled R-Index†††
450mg	90.91	86.36
400mg	95.45	92.56
350mg	95.45	95.87
300mg	95.45	92.15
250mg	90.91	80.17
200mg	63.64	66.12

† Testing had 6 replications for each sample concentration.
†† Group Average R-Index for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average.
††† Pooled R-Index value for each sodium level calculated by compiling all panelist matrix responses and calculating the R-index value.

Appendix I: Preliminary R-Index Results of Reduced Fat Model Emulsions (Test Two)†

Sodium Content	Average R-Index††	Pooled R-Index†††
400mg	97.91	93.66
375mg	100	93.23
350mg	89.58	91.15
325mg	87.5	88.28
300mg	77.08	80.47
275mg	79.17	84.11
250mg	77.08	80.47
225mg	72.92	68.06
200mg	62.5	64.32
175mg	43.75	53.73

† Testing had 20 replications for each sample concentration.
†† Average R-Index value for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average
††† Pooled R-Index value for each sodium level obtained by compiling all panelist matrix responses and calculating the R-index value

Appendix J: Preliminary R-Index Results of Reduced Fat Model Emulsions (Test Three)†

Sodium Content	Average R-Index††	Pooled R-Index†††
350mg	87.5	87.5
325mg	79.17	79.17
300mg	75.00	77.78
275mg	70.83	79.17
250mg	75.00	75.00
225mg	70.83	62.5
200mg	66.67	63.89
175mg	29.17	48.61

† Testing had 8 replications for each sample concentration.
†† Average R-Index value for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average
††† Pooled R-Index value for each sodium level obtained by compiling all panelist matrix responses and calculating the R-index value

Appendix K: Preliminary R-Index Results of Low Fat Model Emulsions (Test One)[†]

Sodium Content	Average R-Index[††]	Pooled R-Index[†††]
350mg	95.45	96.69
300mg	100	99.59
250mg	100	96.28
200mg	90.91	90.50

[†] Testing had 4 replications for each sample concentration.
[††] Average R-Index value for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average
[†††] Pooled R-Index value for each sodium level obtained by compiling all panelist matrix responses and calculating the R-index value

Appendix L: Preliminary R-Index Testing Results of Low Fat Model Emulsions (Test Two)†

Sodium Content	Average R-Index††	Pooled R-Index†††
200mg	87.5	93.66
190mg	81.25	81.42
180mg	72.92	70.66
170mg	51.04	51.39
160mg	56.25	55.56

† Testing had 10 replications for each sample concentration.
†† Average R-Index value for each sodium level calculated by the R-index value obtained from each individual matrix response and combined to get an average
††† Pooled R-Index value for each sodium level obtained by compiling all panelist matrix responses and calculating the R-index value

Appendix M: Average pH Values† of Emulsion Formulations†

	Reduced-fat, 150 mg Na	Reduced-fat, 350 mg Na	Low-fat, 150 mg Na	Low-fat, 200 mg Na
Day 0††	4.80[a] ± 0.000	4.98[a] ± 0.006	4.76[a] ± 0.006	4.79[a] ± 0.021
Day 1	5.42[a] ± 0.046	5.61[a] ± 0.081	5.36[a] ± 0.006	5.42[a] ± 0.025
Day 2	5.53[a] ± 0.036	5.75[a] ± 0.010	5.46[a] ± 0.020	5.45[a] ± 0.015
Day 3	5.53[a] ± 0.036	5.88[a] ± 0.006	5.50[a] ± 0.015	5.49[a] ± 0.010
Day 4	5.41[a] ± 0.006	5.68[a] ± 0.015	5.45[a] ± 0.031	5.43[a] ± 0.006
Day 5†††	5.86[a] ± 0.015	6.00[a] ± 0.015	5.82[a] ± 0.012	5.87[a] ± 0.010

†The values are presented as mean ± standard deviation (n=3). Values in the same row with same superscript letter are not significantly different ($\alpha \leq 0.05$).
††Day 0 = day emulsion was made
†††Day 5 = final day of pH testing

Appendix N: Average Viscosity (cP) of Emulsion Formulations†

	Reduced-fat, 150 mg Na	Reduced-fat, 350 mg Na	Low-fat, 150 mg Na	Low-fat, 200 mg Na
Day 0††	4.21[a] ± 0.099	4.65[a] ± 0.035	3.44[a] ± 0.028	3.54[a] ± 0.021
Day 1	4.24[a] ± 0.021	4.55[a] ± 0.021	3.43[a] ± 0.049	3.55[a] ± 0.021
Day 2	4.10[a] ± 0.092	4.46[a] ± 0.190	3.33[a] ± 0.014	3.41[a] ± 0.035
Day 3	4.10[a] ± 0.000	4.20[a] ± 0.000	3.30[a] ± 0.000	3.43[a] ± 0.000
Day 4	4.02[a] ± 0.000	4.30[a] ± 0.000	3.30[a] ± 0.000	3.48[a] ± 0.000
Day 5†††	4.08[a] ± 0.071	4.32[a] ± 0.064	3.34[a] ± 0.071	3.33[a] ± 0.078

†The values are presented as mean ± standard deviation (n=3). Values in the same row with same superscript letter are not significantly different ($\alpha \leq 0.05$).
††Day 0 = day emulsion was made
†††Day 5 = final day of viscosity testing

Appendix O: Recruitment Email for Threshold Study

Emulsion Study

Participate in a study on emulsions and receive $50!

You must meet the following requirements to be eligible:

1. Be interested and willing to taste oil-in-water emulsions
2. Be willing to participate in one prescreening session the week of **November 17th**
3. Be available for **TEN, 30 - minute sessions EVERY DAY (MONDAY through FRIDAY) for the weeks of December 1st** and **December 8th**
4. Must not have allergies to soybean oil or any other ingredients outlined in the study

If you are interested in participating, please complete the survey link below for participation in the prescreening session.
https://uiuc.qualtrics.com/SE/?SID=SV_5tpYBzqadDQuTbf

Please contact Ginnefer Cox at fshn-sensory@illinois.edu for more information.

Thank you for considering participating in my test!

Ginnefer Cox

Graduate Student, Sensory Group

Appendix P: Screener Questionnaire for Threshold Study

Thank you for your interest in participating in a sodium threshold study. Before the test, I need to ask you a few questions to help organize the test. All information will be kept confidential and will be seen only by the researchers.
If you have any questions or concerns, feel free to contact Ginnefer Cox at fshn-sensory@illinois.edu. Please send your completed form to fshn-sensory@illinois.edu as well.

Name: _____

Email Address: _____

1. **Are you interested in participating in a sodium difference threshold study?**
   ☐ YES ☐ NO

2. **Are you over 18 years old?** ☐ YES ☐ NO

3. **The prescreening test session will examine your ability to detect certain tastes. Please select if you are allergic or intolerant to the following:**
   Sucrose ☐ YES ☐ NO ☐ DO NOT KNOW
   Caffeine ☐ YES ☐ NO ☐ DO NOT KNOW
   Sodium Chloride ☐ YES ☐ NO ☐ DO NOT KNOW
   Monosodium Glutamate ☐ YES ☐ NO ☐ DO NOT KNOW
   Citric Acid ☐ YES ☐ NO ☐ DO NOT KNOW
   6-n-propylthiouracil ☐ YES ☐ NO ☐ DO NOT KNOW

4. **The difference threshold taste will involve tasting oil-in-water emulsions. Please select if you are allergic or intolerant to the following ingredients:**
   Soybean oil ☐ YES ☐ NO ☐ DO NOT KNOW
   Gluten ☐ YES ☐ NO ☐ DO NOT KNOW
   soy lecithin ☐ YES ☐ NO ☐ DO NOT KNOW
   xanthan gum ☐ YES ☐ NO ☐ DO NOT KNOW

5. **Desired time to participate for prescreening: Check times when you are available to participate.**

Time of Day	**Availability**				
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
8-9am	☐	☐	☐	☐	☐
9-10am	☐	☐	☐	☐	☐
10-11am	☐	☐	☐	☐	☐
11-12pm	☐	☐	☐	☐	☐
12-1pm	☐	☐	☐	☐	☐
1-2pm	☐	☐	☐	☐	☐
2-3pm	☐	☐	☐	☐	☐
3-4pm	☐	☐	☐	☐	☐
4-5pm	☐	☐	☐	☐	☐

Appendix Q: Taste Identification Test for Threshold Study

Name: ________________________________ Date: _________

SOLUTION TESTS

Your task is to recognize the basic taste of each sample solution (sweet, salty, sour, bitter, or umami). Write in the blank which taste you perceive. When the sample tastes like water mark with a "0". If your recognition is questionable, write a question mark "?". Retasting is allowed.

For each sample, take the sample into the mouth in sips and move it around in such a way that it touches all parts of the tongue. Do not swallow the sample; use spit cups. Rinse between samples with spring water.

Sample Codes	Basic Taste
976	umami (MSG solution 0.5 g/L)
740	blank
439	sweet (sucrose solution 20 g/L)
300	salty (NaCl solution 0.8 g/L)
143	bitter (caffeine solution 0.7 g/L)
279	sour (citric acid solution 0.6 g/L)

PAPER TEST

Place the piece of filter paper on your tongue, close your mouth, and wet the paper with saliva for 10 seconds.

Do you perceive a taste? ______________________

If so, what do you taste? ______________________

On a scale of 1-10 (ten being the strongest possible taste), circle the number that represents how strong the taste you perceive is (if you didn't perceive anything, leave this blank).

1 Very weak
2
3
4
5
6
7
8
9
10 Very Strong

Appendix R: Sensory Ballot for Threshold Study

Take time to familiarize yourself with the **NOISE** sample and rinse protocol:

1) Bread (compress between the tongue and roof of mouth, expectorate)
2) Carbonated water (swirl around entire mouth, expectorate)
3) Warm water (swirl around entire mouth, expectorate)
4) Room temperature water (swirl around entire mouth, expectorate)

If you need more **NOISE** sample or rinses at any time, please alert the test administrators by flipping the light switch.

Please follow the rinse protocol below:

1) Bread (compress between the tongue and roof of the mouth, expectorate)
2) Carbonated water (swirl around entire mouth, expectorate)
3) Warm water (swirl around entire mouth, expectorate)
4) Room temperature water (swirl around entire mouth, expectorate)

Once you are done rinsing, click 'Next Question'

You will now taste **Sample __**
Please check that you have Sample __ before continuing

Place a spoonful of **Sample __** into your mouth and **click 'Next Question'**

Please hold **Sample __** in your mouth until the time below is finished (5 seconds)

Compare **Sample __** to the **NOISE** and indicate if it is a signal sure, signal unsure, noise unsure, or noise sure. You can retaste the **NOISE** as often as needed.

☐ Noise, SURE
☐ Noise, UNSURE
☐ Signal, UNSURE
☐ Signal, SURE

Appendix S: Questionnaire for Threshold Study

Question	Selection of Responses
1. Please select the range that your age fits in.	☐ 18-24 years old ☐ 25-29 years old ☐ 30-34 years old ☐ 35-39 years old ☐ 40-44 years old ☐ 45-49 years old ☐ 50-54 years old ☐ 55-59 years old ☐ 60-64 years old ☐ 65-69 years old ☐ 70 years old or older
2. Please select your gender.	☐ Male ☐ Female ☐ Prefer Not to Answer
3. How do you describe yourself?	☐ White or Caucasian ☐ Black or African American ☐ Hispanic or Latino ☐ Asian ☐ Native Hawaiian or Other Pacific Islander ☐ American Indian or Alaska Native ☐ More than one race ☐ Other ☐ Prefer not to answer
4. Have you been medically diagnosed as having hypertension (high blood pressure)?	☐ Yes ☐ No
5. Have you been medically diagnosed as having prehypertension?	☐ Yes ☐ No
6. Do you have a family history of hypertension (high blood pressure)?	☐ Yes ☐ No
7. Do you have a family history of prehypertension?	☐ Yes ☐ No
8. How much sodium do you consume in your daily diet?	☐ 1500 milligrams daily, equivalent to roughly 1/2 teaspoon salt ☐ 2400 milligrams daily, equivalent to roughly 1 teaspoon salt ☐ 4800 milligrams daily, equivalent to roughly 2 teaspoons salt ☐ More than 4800 milligrams daily ☐ Do not know
9. How much fat do you consume in your daily diet?	☐ 20 grams daily, equivalent to roughly 10% of total daily calories ☐ 65 grams daily, equivalent to roughly 30% of total daily calories ☐ 100 grams daily, equivalent to roughly 45% of total daily calories ☐ More than 100 grams of fat daily ☐ Do not know
10. How concerned are you about the amount of sodium that is in your daily food intake?	☐ Very concerned ☐ Somewhat concerned ☐ Not concerned
11. How concerned are you about the amount of fat that is in your daily food intake?	☐ Very concerned ☐ Somewhat concerned ☐ Not concerned
12. How important is sodium content to you when purchasing a food product?	☐ Very concerned ☐ Somewhat concerned ☐ Not concerned
13. How important is fat content to you when purchasing a food product?	☐ Very concerned ☐ Somewhat concerned ☐ Not concerned