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INVESTIGATING SATIATING PROPERTIES OF FOODS

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by

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ABSTRACT

The current rates of overweight and obesity indicate that dietary strategies are needed to help individuals moderate energy intake in an eating environment that encourages overconsumption. Research has shown that dietary approaches such as reductions in food energy density (kcal/g), consumption of pre-portioned entrées, and consumption of satiety-enhancing foods can decrease energy intake. There are still questions that need to be explored, however, in order to provide effective recommendations for individuals seeking approaches to curb energy consumption. First, reductions in energy density decrease energy intake, but it is not known if the effects depend on the way that energy density is reduced. Secondly, pre-portioned entrées are commonly consumed to help control portion size and limit energy intake, yet the influence of their characteristics on energy intake has not been well studied. Lastly, foods that enhance satiety can reduce overconsumption, but the availability of large portions of energy-dense foods in the current food environment may counter their benefits. Examination of these issues will lead to better dietary strategies to help decrease energy intake.

The first study examined whether three commonly used methods of reducing energy density (decreasing fat, increasing fruit and vegetables, and adding water) differed in their effects on energy intake across the day. In a crossover design, 59 adults (29 men and 30 women) consumed breakfast, lunch, and dinner in the laboratory on one day a week for four weeks. Across conditions, the entrées were either standard in energy density or were reduced in energy density by 20% using one of the three methods. Each meal included a manipulated entrée along with unmanipulated side dishes; all foods were consumed *ad libitum.* It was found that reducing the energy density of entrées significantly decreased daily energy intake compared to the standard energy density entrées (mean intake 2667±77 kcal/day; $p < 0.0001$). The mean decrease was 396±44 kcal/day when fat was reduced, 308±41 kcal/day when fruit and vegetables were

increased, and 230±35 kcal/day when water was added. Comparison of the three methods of energy density reduction showed that daily energy intake was lower when fat was decreased but was not significantly different between increasing fruits and vegetables or adding water.

The second study determined how variations in the energy content and energy density of pre-portioned entrées combine to influence daily energy intake. In a crossover design, 68 non-dieting adults (28 men and 40 women) were provided with breakfast, lunch, and dinner once a week for four weeks. Each meal included a manipulated pre-portioned entrée that was compulsory, followed by a variety of unmanipulated discretionary foods that were consumed ad libitum. Across conditions, the entrées were varied in both energy content and energy density between a standard level (100%) and a reduced level (64%). The results showed that in men, reductions in the energy content and energy density of pre-portioned entrées acted independently and added together to decrease daily energy intake (both $p < 0.01$). A 38% reduction in energy content led to an 11% decrease in energy intake (291±75 kcal), and a 38% decrease in energy density led to a 6% decrease in energy intake (154±46 kcal). Simultaneously decreasing the energy content and energy density reduced total energy intake in men by 16% (445 ± 47 kcal/day; $p < 0.0001$). In women, the entrée factors also had independent effects on energy intake at breakfast and lunch, but at dinner and for the entire day the effects depended on the interaction of the two factors ($p < 0.01$). Simultaneously decreasing the energy content and energy density reduced daily energy intake in women by 14% (289 ± 35 kcal/day; $p < 0.0001$).

The third study tested the influence on meal energy intake of varying the energy density and portion size of food consumed after a preload shown to promote satiety. In a crossover design, 46 adult women were served lunch on six days. On four days they ate a compulsory salad (300 g, 0.33 kcal/g). Unlike previous studies, instead of varying the preload, the subsequent test meal of pasta was varied between standard and increased levels of both energy density (1.25 or 1.66 kcal/g) and portion size (450 or 600 g). On two control days a salad was not served.

Following consumption of the salad, the energy density and portion size of the test meal independently affected meal energy intake (both $p < 0.02$). Serving the higher-energy-dense pasta increased test meal energy intake by 153 ± 19 kcal and serving the larger portion of pasta increased test meal energy intake by 40 ± 16 kcal. Compared to having no salad, consuming the salad decreased test meal intake by 123 ± 18 kcal.

These three studies provide useful information concerning dietary strategies that can be used to moderate energy intake and how the eating environment may influence their effects. Findings from the first study indicate that a variety of diet compositions can be recommended to reduce overall dietary energy density in order to moderate energy intake. Reductions in energy density by decreasing the fat content, increasing the proportion of fruit and vegetables, and adding water can all decrease energy intake over the day. The second study highlights the importance of considering the characteristics of pre-portioned entrées. Variations in the energy content and energy density of these foods affect daily energy intake and could influence the effectiveness of such foods for weight management. Results from the third study emphasize the importance of considering the environment in which satiety-enhancing foods are consumed. The effects of these foods can be influenced by the energy density and portion size of other foods at the meal. Collectively, these studies highlight the beneficial effects of reducing energy density by various methods and in the context of pre-portioned entrées, but suggest that an environment with large portions of energy-dense foods may oppose the effects of satiety-enhancing foods.

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CHAPTER 1

Introduction

The prevalence of overweight and obesity has risen over the previous decades, with data showing that 33.8% of the adult population in the United States is overweight, and 68% is either overweight or obese (1). Obesity is a major health concern because it is associated with numerous comorbidities such as type 2 diabetes, cardiovascular disease, osteoarthritis, and some cancers (2). Although the causes of obesity are multifactorial and include genetics, physiology, culture, behavior, and the environment (3), only some of these risk factors (eating behavior and the environment) affect everyone. Energy from food is an essential requirement, but the current environment is conducive to overeating, with large portions of energy-dense foods that are palatable, cheap, and readily available (4). As a result of the health consequences of obesity and an obesogenic environment that encourages overconsumption, effective strategies are needed that moderate energy intake and facilitate weight management. According to a meta-analysis, successful weight loss interventions were those that included dietary strategies either alone or in combination with physical activity (5). These findings emphasize the importance of making dietary changes in order to reduce energy intake and manage body weight. Dietary strategies to moderate energy intake include reducing energy density (6), consuming pre-portioned entrées (7), and incorporating satiety-enhancing foods into the diet (8).

ENERGY DENSITY

Energy density: what is it?

Energy density is defined as the amount of energy in a particular amount of food (kcal/g) and ranges from 0 kcal/g to 9 kcal/g. A food’s energy density is influenced by its macronutrient composition and moistness content. Of the macronutrients, fat has the largest influence on energy density because it contains 9 kcal/g while protein and carbohydrate each contain only 4 kcal/g. Water, however, has the greatest influence on energy density because it adds weight without providing energy (0 kcal/g). Since fruits and vegetables have a high water content, they also have a low energy density because they add weight while providing minimal energy. Thus, even high-fat foods can have their energy density lowered by the incorporation of water or water-rich fruits and vegetables. Because of these various influences, foods can be reduced in energy density by a number of commonly used methods such as decreasing the fat content, increasing the proportion of fruits and vegetables, or adding water, and other less commonly used methods like using fat or sugar substitutes. Both single methods and a combination of methods of energy density reduction have been investigated for their effects on satiety and satiation (Table 1.1). Since energy density can be reduced by a variety of methods, the mechanisms that could affect intake of the three commonly used methods will be discussed throughout the following sections.

Variations in energy density: satiety studies

Satiety: how it is measured

Satiety refers to the effect of a food after it has been eaten (9). It can be assessed by measuring intake at a subsequent test meal using the preloading paradigm, recording hunger and fullness ratings over a specified interval, or determining the length of time until initiation of the next meal or snack (9). With the preloading paradigm, a preload (first course) is provided that varies in its characteristics and must be consumed in its entirety. After a specified amount of time, a test meal is served, which is not varied and is consumed ad libitum; the satiating effect of the preload is typically determined by intake at the test meal (9, 10). The preloading paradigm or measurement of appetitive ratings are often used separately or in combination to assess satiety. Several studies have shown that preloads reduced in energy density decrease energy intake and increase fullness ratings. These preloads have primarily been modified in energy density by increasing the water content (11-14) or using a combination of methods (15-17).

Reducing energy density by adding water

The addition of water to a food does not add energy or change the macronutrient composition, but it does alter the weight or volume of the food. For this reason, reductions in energy density by adding water can show that decreases in energy intake at the test meal are independent of the macronutrient and energy content of the preload (11-14). Consumption of a milk-based drink that was consumed orally (range of 1.5 to 0.8 kcal/g) (11) or infused through a nasogastric tube (1.0 or 0.5 kcal/g) (12) decreased energy intake when it was lower in energy density and larger in volume. The combined reduction in energy density and increase in volume could influence satiety through effects on cognitive and orosensory processes (18, 19). Research has shown that when people were asked to look at pictures of foods matched in energy but varied in portion size, low-energy-dense foods were chosen as being able to prevent hunger for the longest time compared to high-energy-dense foods (18). The larger portion sizes in the low-energy-dense pictures may be one reason why these foods were chosen to delay hunger longer. Another reason for the finding that a large volume of a preload increased fullness ratings and decreased energy intake (11, 13) could be that satiety is influenced through prolonged oral exposure as a result of the length of time required to consume the soup (19). Thus, an increase in the volume of foods through the addition of water may enhance satiety by affecting both cognitive and orosensory processes.

It is also possible that preloads reduced in energy density with water influence energy intake through effects on gastric distention and gastric emptying (20, 21). When preloads varying in volume and energy content were infused intragastrically, only the volume was found to decrease energy intake (12). This finding indicates that the ability of large volume preloads to reduce energy intake is not dependent on visual cues or orosensory processes. Research using gastric balloons has also shown that gastric distention can reduce energy intake (20), suggesting that reductions in energy density that increase the volume of a preload could affect intake by increasing gastric distention. Reducing energy density by adding water and increasing volume may not lead to reductions in energy intake, however, if the water is not incorporated into the food. When the same amount of water was either incorporated into a casserole preload to make a soup or served as a beverage along with the casserole preload, energy intake was decreased and fullness was increased only when the soup was consumed (13). One explanation for this may be differences in gastric handling and gastric emptying (21). In another example, when energy density was matched, slower gastric emptying rates were found for a homogenized meal (water incorporated into the food) compared to a solid meal (water consumed as a beverage) (21, 22). Together, these findings suggest that effects on gastric distention and gastric emptying could influence the effects on satiety of preloads reduced in energy density.

Reducing energy density by a combination of methods

Reductions in energy density have been tested using a combination of water, vegetable, carbohydrate, and fat manipulations (15-17). Preloads that are varied in energy density by a combination of such methods can be used to determine whether the portion size and energy density of a preload combine to influence satiety. For example, in one study, two different portion sizes of salad preloads were modified in energy density by altering both the fat and vegetable contents (15). Consumption of a low-energy-dense, first-course salad decreased energy intake compared to having no salad, and the large portion, low-energy-dense salad (300 g, 0.33 kcal/g) led to the greatest reduction in energy intake. Similar to studies that have varied the water content, the larger weight or volume of food provided from the largest, low-energy-dense salad could have influenced cognitive, orosensory, and gastric mechanisms. Consumption of low-energy-dense foods containing extra vegetables could also influence gastric emptying through their fiber content and effects on post-ingestive hormonal responses (23). Reducing the energy density of preloads by a combination of methods can enhance satiety and this effect may be attributable to the numerous biological processes that affect intake.

Variations in energy density: satiation studies

Satiation: how it is measured

Satiation refers to the processes that terminate eating during a meal and is tested by measuring ad libitum consumption (9). When the goal is to determine how manipulations in energy density influence intake, a similar weight (portion) of food is often served in order to avoid confounding issues (24). Since people can choose how much or how little they want to eat, the palatability of the test foods can affect intake if their sensory characteristics are not well-matched (25). One way to lessen sensory differences is to use a combination of methods to reduce energy density. Adding water moistens foods whereas decreasing fat reduces moistness; thus, reducing energy density using both methods can help to maintain appropriate moistness levels. Another way to minimize sensory differences is to chop ingredients and use mixed dishes. Increasing the proportion of fruits and vegetables, for example, can alter the amount of chewing required and change the appearance, especially if they are in whole pieces. Differences in any of these sensory characteristics may affect the tendency for people to consume a consistent weight of food when energy density is varied (26-28). Studies on the effects of ad libitum intake have reduced energy density using single methods such as decreasing the fat content (29-32), increasing the proportion of fruits and vegetables (27, 33), or using a combination of methods (26, 28, 34-40). Collectively, these studies have shown that a variety of methods of energy density reduction decrease ad libitum energy intake.

Reducing energy density by decreasing the fat content

Reductions in energy density by decreasing the fat content have been investigated by manipulating the fat content of foods (29, 30) or by comparing diets that differ in the fat content of prepared foods, such as regular-fat versus low-fat products (31, 32). These studies have tested changes in energy density by varying fat over periods ranging from one day up to 11 weeks (29, 32). When three levels of fat were tested over 7 days (20, 40, and 60% fat), daily energy intake was found to be lower when the low-fat, low-energy-dense diet was consumed (29). Similar results were shown over 2 weeks (31) and 11 weeks (32) with low-fat diets that contained approximately 20% energy from fat. From these longer term studies that decreased the fat content of the diets, it was shown that reductions in energy density by this method had effects on intake that persist over multiple weeks. Since reductions in energy density by decreasing the fat content alter the proportion of macronutrients, it is possible that these changes influence intake by affecting biological processes such as gastric emptying and post-ingestive hormonal responses (41, 42). Alterations in these mechanisms could account for the sustained reductions in energy intake over multiple weeks when energy density is reduced by decreasing fat.

Reductions in energy density: are they independent of the macronutrient content?

In many studies, especially those that manipulate fat to reduce energy density, it was not clear whether decreases in energy intake were attributable to the change in fat content or the change in energy density. In order to determine whether energy density has effects on energy intake that are independent of fat, other methods of energy density reduction need to be used, such as varying both the vegetable and carbohydrate content. Comparison of entrées that were low-fat/low-energy-dense, low-fat/high-energy-dense, or high-fat/high-energy-dense showed that varying the energy density while maintaining the fat content decreased energy intake over 4 days (34). In contrast, when entrées were provided that were matched for energy density but varied in fat content, there were no significant differences in energy intake. Additional research has shown that when energy density is maintained, altering the fat content does not affect intake (34, 43). Although varying the protein content when energy density is held constant has been shown not to affect intake (43, 44), a few recent studies have suggested that larger differences in protein content may affect energy intake independent of energy density (45, 46). In comparison, several studies have shown that when the proportion of macronutrients is held constant, energy intake decreases when energy density is reduced (26, 28, 36). Thus, while it has consistently been shown that reductions in energy density have effects on intake that are independent of macronutrient content, some conflicting evidence suggests that variations in protein, but not fat, may influence intake independent of energy density.

Reducing energy density by increasing the vegetable content

The incorporation of whole or puréed vegetables into mixed dishes has been used to reduce energy density and decrease energy intake (27, 33). When entrées at all three meals over one day were reduced in energy density by either 15 or 25%, daily energy intake decreased as the energy density of the entrées decreased (27). In another study, vegetables were added into lunch and dinner entrées and led to a reduction in energy intake at both meals compared to the condition in which the vegetables were not included in the entrées (33). It is likely that incorporation of vegetables into foods affects intake through multiple processes. Increasing the vegetable content of entrées can lead to greater fiber intakes and thus influence gastric emptying rates (23). Depending on the types and amounts of vegetables, however, the increase in fiber content may not be enough to elicit these physiological responses. Increasing the vegetable content can also influence the amount of chewing required, which in turn could affect intake by increasing orosensory exposure (23, 47). Regardless of whether vegetables are whole, chopped, or puréed, incorporation of these foods into dishes reduces energy density and decreases energy intake.

Reducing energy density by a combination of methods

Numerous studies have investigated how using a combination of methods to reduce energy density affects energy intake (26, 28, 34-40). The methods most commonly combined include decreasing fat, increasing fruits and vegetables, and adjusting the carbohydrate content. In one of the early studies looking at the effects of energy density, participants were provided with either a low- or high-energy-dense diet for 5 days (35). The low-energy-dense diet contained lots of fruits and vegetables, whole grains, dried beans, and little fat (0.7 kcal/g), whereas the high-energy-dense diet contained larger amounts of fat and sugar in the form of meat and desserts (1.5 kcal/g). Average daily energy intakes were lower for the low-energy-dense diet compared to the high-energy-dense diet. In this study, the diets were composed of foods that were naturally low or high in energy density. Another way of looking at a combination of methods is to alter the energy density of mixed dishes or other prepared foods (26, 28, 34, 36-40). In studies that have reduced the energy density of foods using various methods, decreases in energy intake were found at a meal (38), over the day (36, 37), and over multiple days (26, 28, 34, 39, 40) while hunger and fullness ratings did not usually differ (26, 28, 34, 36, 38-40). Reductions in the energy density of lunch and dinner entrées and part of the evening snack over a two day period (1.3., 1.1, or 0.8 kcal/g) showed that a similar weight of food was consumed across conditions, leading to a lower energy intake in the low energy density condition that was not associated with differences in hunger or fullness (26). The tendency to consume a similar weight of food when energy density varies, together with effects on physiological processes, could account for the robust effects on energy intake when energy density is reduced.

Energy density: does the method differentially affect intake?

Although reductions in energy density by all three of these methods (decreasing fat, increasing fruits and vegetables, and adding water) have been shown to decrease energy intake, these methods have never been directly compared. There is a complex array of factors that influence intake, including cognitive, orosensory, gastric, and post-ingestive processes, in addition to palatability and sensory characteristics. The various methods of energy density reduction could differentially affect intake through a series of these factors, which could lead to effects on intake that would be short-lived or persist over the day to affect the magnitude and time course. Because of the numerous mechanisms involved, some researchers have suggested that reductions in energy density could differ in the persistence of their effects on intake beyond a meal (48-51). Decreases in fat and increases in fruit and vegetables, for example, have been proposed to have effects on intake that would persist, whereas the addition of water has been proposed to have effects on intake that are transient. Thus, it is possible that energy consumption over the day could differ across these three methods of energy density reduction.

PRE-PORTIONED ENTRÉES

Pre-portioned foods: what are they?

Pre-portioned foods encompass a wide variety of commercially available products that range from beverages to portion-controlled snack bars and solid entrées. Beverages or shakes and bars are typically fortified with vitamins and minerals and are available in a limited assortment of flavors. Such beverages or shakes are termed liquid meal replacements. In comparison, solid pre-portioned entrées are similar to frozen entrées and other commercially available products. These entrées are available in many different varieties. Both dieters and non-dieters consume pre-portioned foods. Dieters often consume these foods because they are convenient, limit portions, and provide a structured eating plan. In particular, pre-portioned foods allow individuals to structure their eating environment so that the types and portion sizes of foods to which they are exposed is limited during the day. Non-dieters also use these products for their convenience and reasonable cost.

Much of the research on pre-portioned foods has focused on the use of liquid meal replacements and their effects on weight loss. More recently, studies have placed a greater focus on the use of solid pre-portioned foods, such as entrées, and their effects on weight loss. The effectiveness of meal replacements to decrease body weight has undergone systematic evaluation by meta-analyses (7, 52, 53) and for both the Academy of Nutrition and Dietetics' Evidence Analysis Library (54) and a weight management position paper (55). The available evidence indicates that the consumption of these foods within a reduced energy diet can decrease weight compared to reduced energy diets without such foods. As a result of the available evidence, the European Food Standards Agency has recently approved claims stating that, "substituting two daily meals with meal replacements helps to lose weight in the context of energy restricted diets" (56). Thus, the use of meal replacements can beneficially influence body weight (Table 1-2).

Pre-portioned foods: studies using liquid meal replacements

Liquid meal replacements are typically prescribed for two meals per day during weight loss and one to two meals per day for weight maintenance (57-66). These shakes provide between 200-250 kcal per serving and are meant to replace all other foods at meals. Some of the studies that primarily use shakes also provide bars or soups for snacks or as alternates to meals (57-63, 67). Many clinical trials that investigate the efficacy of these meal replacements also include an energy-restricted control group that is usually based on standard dietary guidance (58-64, 67). Incorporation of liquid meal replacements into the diet for one year has been shown to result in greater weight loss over periods ranging from 3 months to 4 years compared to the control group (57, 58, 60-64, 67). Of these trials, only a limited number have collected data on energy intake (59, 60-62), and none have measured ratings of hunger and fullness. The few that have measured energy intake have not found any significant differences between groups. Collectively, research on liquid meal replacements has shown the utility of these products for weight loss and weight maintenance when consumed within an energy-restricted diet.

Pre-portioned foods: studies comparing liquids versus solids

Liquid meal replacements have been suggested to be less satiating than solid pre-portioned meals (68, 69). Comparison of a either a liquid (shake) or solid (bar) meal replacement that was matched for energy content showed that participants consumed 13% more food at the subsequent test meal after the liquid compared to the solid meal replacement (68). Area under the curve ratings for hunger were also higher when liquid meal replacements were consumed compared to solid meal replacements (68, 69). Based on these results, it is possible that a diet plan that includes solid pre-portioned foods could be more effective than one that includes liquid meal replacements.

Pre-portioned foods: studies using solid entrées

Solid pre-portioned entrées or ready-to-eat cereal meals are often prescribed for 2-3 meals per day along with specified servings of fruits, vegetables, and low-fat dairy although a few studies have encouraged more frequent consumption (70, 71). These foods provide between 100 (70) to 400 kcal per serving (72, 73). Participants are able to self-select from a variety of options at breakfast, lunch, and dinner meals, depending on the meals at which the pre-portioned foods will be consumed. One advantage of solid pre-portioned meals is that these foods might be more sustainable because of the greater variety of options; this could allow for less monotony and better long-term compliance. Consumption of these foods has been examined for periods of 4 weeks to 1 year (72-83). Compared to self-selected control diets, inclusion of pre-portioned entrées into energy-restricted diets over multiple weeks resulted in greater weight loss (72-83). In studies that collected dietary intake data, most have found no significant differences between the pre-portioned meal group and the control group (72-76, 84), although one found lower energy intakes in the control group using the American Heart Association dietary guidance (but weight loss was less) (79), and one found lower energy intakes compared to the non-diet control (82). Of the few studies that measured ratings of hunger and fullness, most found no significant differences between groups (70, 71, 77, 84), whereas one study found no significant differences in fullness ratings but an increase in hunger ratings during the active phase when ready-to-eat cereal was included (82). These findings indicate that consumption of solid pre-portioned entrées is a beneficial strategy to reduce body weight.

Pre-portioned foods: do the properties of these meals influence intake?

Research on pre-portioned meals has provided little information on how the characteristics of these foods influence energy intake or hunger and fullness. Studies using the preloading paradigm provide an opportunity to investigate how the satiating effects of such foods are influenced by their properties. It is important to note that most preloading studies have tested foods commonly served as a first course (15, 16, 85-88). Only a few investigations have explored the effects of varying the properties of a compulsory main course (13, 17, 34, 89). Since many commercially available options vary in energy content, energy density, and portion size, it is important to consider how these characteristics could influence the effects of pre-portioned foods, especially solid entrées (Table 1-3).

Although studies have not investigated how varying the energy content of solid pre-portioned entrées influences intake, several investigations have found that increasing the energy content of preloads leads to a reduction in energy intake at the test meal (16, 85-88). In these studies, the energy content of the preload spanned large ranges, such as from 0 to 600 kcal (85) or 120 to 955 kcal (88). When the combined energy contribution from the preload and test meal energy was measured, total energy intake at the meal was greater when a high-energy preload was eaten compared to a low-energy preload (85-87). This suggests that a high-energy preload could lead to greater energy intakes at a meal and thus be problematic for individuals trying to moderate energy intake. On the other hand, low-energy preloads led to greater energy intakes at the test meal as well as an increase in hunger ratings (16, 87, 90); this combination could contribute to greater overall energy intakes, especially if the other available options are large portions of high-energy-dense foods. Given these findings, it is surprising that the European Food Standards Agency stipulated that meal replacement products cannot provide more than 250 kcal/serving in order to carry a weight loss claim (56). This energy level is representative of the typical energy content of liquid meal replacements, however, and much of the work used to support these claims involved the use of such foods. The influence on energy intake of solid pre-portioned entrées that differ in energy content is not well-defined, and variations in energy content of these entrées may have similar effects on intake as have been seen in previous preloading studies.

Alterations in characteristics such as the energy density and portion size of compulsory main courses have been shown to affect energy intake (13, 17, 34, 89). Reducing the energy density of an isocaloric main course also increased the portion size and led to a decrease in both test meal and total meal energy intakes (13, 89). In these studies, the energy density levels varied from 2.7 to 1.25 kcal/g (89) or 1.03 to 0.44 kcal/g (13). The reductions in energy density also decreased hunger and increased fullness after the equicaloric first course (13, 89). Another investigation provided isocaloric compulsory entrées at three meals per day along with discretionary foods that were consumed ad libitum, and found that reductions in entrée energy density (1.58 to 1.05 kcal/g) decreased daily energy intake but did not significantly affect hunger and fullness ratings (34). Both of these studies examined the effects of serving compulsory main courses that were matched in energy content but varied in energy density and portion size. In comparison, serving compulsory breakfast and mid-morning snack preloads showed the effects of simultaneously varying the energy density, portion size, and energy content (17). Participants received preloads that were high energy density (1175 kcal, 613g, 1.91 kcal/g), low energy density (588 kcal, 613 g, 0.96 kcal/g), or 2x low energy density (1175 kcal, 1226 g, 0.96 kcal/g). Lunch energy intake and hunger ratings were lower but total daily energy intake was higher when the high energy density and 2x low energy density preloads were consumed compared to the low energy density preloads. This indicates that entrées that are reduced in energy density and energy content but provide a similar weight of food might decrease daily energy intake. Together, these results suggest that energy intake could be influenced by the energy density and portion size of pre-portioned entrées.

It remains to be determined how variations in the energy density, portion size, and energy content of pre-portioned entrées would combine to influence energy intake and feelings of hunger and fullness. Consumption of pre-portioned entrées provides structure and eliminates some of the decisions surrounding portion sizes. Since these entrées are eaten along with other discretionary foods at meals, intake of these other foods will depend on the satiating capacity of the entrées. If the entrées do not provide enough energy and leave people feeling hungry, they might be more likely to overeat in the presence of large portions and energy-dense foods that are currently available in the eating environment. Thus, it is important to establish how characteristics of pre-portioned entrées influence intake in order to further enhance long-term weight loss and weight maintenance.

SATIETY-ENHANCING FOODS

Satiety-enhancing foods: what are they?

Satiety-enhancing foods are products that have been shown to reduce subsequent energy intake, increase fullness, and decrease hunger (8). Functional foods that contain various proteins and fibers are often at the forefront of satiety research. The literature on this topic is inconsistent, however, as satiety assessment of foods containing similar functional ingredients often lead to inconsistent findings. One reason for the inconsistencies present in the literature could be the method of satiety assessment. A food that either decreases hunger or increases fullness may not decrease subsequent energy intake. Another reason for the inconsistencies could be that test meals with different characteristics are used across studies (91, 92) (Table 1-3). As a result of these discrepancies in the literature, concerns have been raised over the utility and accuracy of satiety claims (93-96). To combat these issues, the European Food Standards Agency now requires a very rigorous process in order to make such claims (8).

Satiety assessment: do the characteristics of the test meal make a difference?

The focus of the preloading paradigm has been on how the characteristics of the preload influence the satiating effects of a food based on energy intake at the test meal (9). As a result, there has been little investigation on how the properties of the test meal could influence satiety assessment. There are two main types of test meals that are used: a single item meal or a buffet-style meal (8, 9). The buffet meal typically contains foods that vary in a number of factors such as macronutrient content, energy density, portion size, and sensory attributes. Many researchers use the buffet meal to investigate whether participants choose specific types of foods at the test meal (i.e. sweet or savory, high-fat or high-carbohydrate) based on the characteristics of the preload. It has been suggested that a single item test meal limits intake because of the lack of variety while a buffet-style test meal reduces the sensitivity to detect intake differences (8). Although both single item and buffet-style test meals are commonly used, the choice of test meal could influence the assessment of satiety.

Interestingly, while issues have been raised about the influence of using a single item or buffet-style test meal, this topic has not been highly researched. Two studies have determined the effects on energy intake of varying the number of items present in the test meal between either a single pasta dish or a buffet-style meal (88, 97). Both investigations served high- and low-energy preloads, but the energy content and type of foods served differed between studies. One study served milkshakes that provided either 240 or 599 kcal (97), whereas the other served different breakfast foods that provided either 120 or 955 kcal (88). In addition, the delay between preload and test meal ranged from 1 hour (97) to 3 hours (88). These differences in study design may be one reason why lower energy intake at the single item test meal was found only for the high-energy preload (97) compared to for both preload energy contents (88). In comparison, another study investigated how the variety of the kinds of sandwiches served at the test meal influenced subsequent energy intake (98). The test meal was either a single condition in which sandwiches with one type of filling were provided or was a variety condition in which sandwiches with three types of filling were provided (98). The results showed that there was a 14% increase in energy intake at the test meal in the variety condition compared to the single filling condition. Together, these studies suggest that increasing the variety of the test meal can influence energy intake and satiety assessment.

Buffet test meals have often been used to determine how the macronutrient or energy content of the preload affects the choice of foods that vary in macronutrient composition (9). Another way of looking at how the macronutrient composition of the test meal influences intake is to systematically vary the composition of the foods offered. In one such study, a compulsory midday meal that varied in energy was provided prior to a dinner test meal that contained 7 foods with at least 50% of the energy from either carbohydrate or fat. (99). It was found that a similar weight of food was consumed yet energy intake at dinner was greater with the high-fat meal compared to the high-carbohydrate meal. However, since the energy density of test meal was higher when the foods were high-fat compared to high-carbohydrate, this could explain that greater energy intake in the high-fat condition. This study provides further support that the characteristics of the test meal affect energy intake but suggests that a higher energy intake associated with a high-fat test meal may be due to the high energy density of the meal.

A few studies have also investigated how the palatability of the test meal influences intake. Both of these studies served the same preloads and test meals but varied the method of preload administration (87, 100). The same volume of low- (63 kcal) or high-energy (360 kcal) soup preloads, which varied in either fat or carbohydrate, were consumed orally (87) or infused intragastrically (100). A pasta test meal that was either bland or palatable was served 30 minutes after consumption of the soup. When the soups were consumed orally, energy intake was higher at the test meal when the pasta was palatable compared to when the pasta was bland (87). In contrast, when the soups were infused intragastrically, only after the high-fat soup was energy intake higher when the test meal was palatable compared to when it was bland (100). These findings suggest that the presence of palatable foods can increase energy intake at the test meal and thus influence satiety assessment.

Satiety assessment: could characteristics present in the eating environment influence satiety?

Results from studies that have varied test meal characteristics suggest that the environment in which satiety-enhancing foods are consumed could influence the assessment of satiety (87, 88, 97-100). These findings, along with the recognition that such foods are consumed outside of a laboratory setting, suggest the importance of considering the real life context in which satiety-enhancing foods are eaten. The current obesogenic environment is characterized by large portions of energy-dense foods, and it is possible that these properties of foods could markedly affect the assessment of satiety.

A number of studies have found that increasing the portion size of foods results in greater energy intakes (24, 38, 39, 101-107). Altering the portion size of main course foods such as macaroni and cheese (24), a sub sandwich (101), or a baked pasta (38, 102) each resulted in an increase in meal energy intake without resultant changes in fullness ratings. Two of these studies provided up to a doubling of the smallest portion (24, 101) while the other two served either 1.5 (102) or 1.8 (38) times the amount of the smallest portion. One thought may be that while people would consume more at a single meal with large portions, this response would not be sustained over a longer period of time, especially with up to a two times greater portion. Contrary to this suggestion, however, energy intakes increased over periods of 2 (39, 103), 4 (104), or 11 (105) days when all foods at meals and snacks were increased in portion size. Furthermore, after 11 days of receiving larger portions, daily area under the curve ratings were higher for fullness and lower for hunger yet participants still consumed more energy (105). This suggests that feeling fuller did not translate into eating less when faced with oversized portions at the next eating occasion. These findings indicate that the satiating effects of a food could be influenced by the portion size of the foods served at the test meal.

As previously discussed, consumption of higher-energy-dense foods increases energy intake because people tend to consume a consistent weight of food when energy density varies, leading to energy intakes that correspond to the energy density of the foods consumed (26-28). The present eating environment contains many energy-dense foods that are large in portion size, however, so it is also important to understand how these properties work together to affect intake. Previous studies have systematically varied the energy density and portion size of either a main course (38) or all foods served over two days (39) and found independent effects on energy intake for both properties. Since the energy density and portion size of foods independently increase energy intake, they also add together to have even greater effects on intake (38, 39). For example, participants consumed 56% more energy from the meal with the largest portion of the high-energy-dense pasta than from the meal with the smallest portion of the low-energy-dense pasta (38). Even with substantial differences in energy intake, ratings of hunger and fullness did not vary. The energy density and portion size of foods have a large influence on energy intake, and it is possible that simultaneous variations in these properties could change the apparent satiety value of a food.

Summary

The current obesogenic environment encourages overconsumption of energy, indicating that dietary strategies are needed to help individuals moderate energy intake. Reducing energy density, consuming pre-portioned entrées, and incorporating satiety-enhancing foods into the diet can decrease energy intake. This dissertation extends previous research in each of these areas and investigates how various properties of foods influence satiety and satiation.

Study 1: Does the method used to reduce energy density have different effects on energy intake?

Reductions in energy density have been promoted by government and health organizations as a strategy to decrease energy intake. A number of methods can be used to reduce the energy density of foods, including decreasing the fat content, increasing the proportion of fruits and vegetables, and adding water. Previous research has shown that all of these methods decrease energy intake, yet studies have not examined whether the effects on intake differ according to the method of energy density reduction. These three methods likely affect energy intake through a variety of biological mechanisms. For this reason, some researchers have proposed that the methods would differ in their effects on energy intake over the day. The purpose of this study was to determine whether energy intake at individual eating occasions and over the day differed when the entrées at main meals were reduced in energy density by 20% using three different methods.

Specific aims and hypotheses for study 1:

Aim 1: To test the effects on meal and daily energy intake of reducing entrée energy density by 20% at breakfast, lunch, and dinner

Hypothesis 1: Energy intake at meals and over the day will decrease when entrées are reduced in energy density compared to entrées that are higher in energy density.

Aim 2: To test the effects on meal and daily energy intake of reducing entrée energy density by three different methods at breakfast, lunch, and dinner

Hypothesis 2: Energy intake at meals and over the day will vary according to the method of energy density reduction.

Study 2: Do alterations in the energy density and energy content of pre-portioned entrées influence energy intake?

Consumption of pre-portioned foods such as liquid meal replacements and solid pre-portioned entrées has been shown to enhance weight loss compared to self-selected diets. Although much of the research has focused on the use of liquid meal replacements, studies have shown that these products are less satiating than their solid equivalents. Solid pre-portioned entrées also may be more sustainable because they offer a greater variety. Little is known, however, about how the characteristics of these foods influence energy intake and feelings of hunger and fullness. The purpose of this study was to examine the effects over the day of varying the energy density and energy content of pre-portioned entrées served at breakfast, lunch, and dinner.

Specific aims and hypotheses for study 2:

Aim 1: To test the effects on daily energy intake of varying the energy density and energy content of pre-portioned entrées

Hypothesis 1: Reductions in the energy density and energy content of pre-portioned entrées will act independently and additively to decrease daily energy intake.

Aim 2: To test the effects on daily energy intake of matching the portion size but varying the energy density and energy content of pre-portioned entrées

Hypothesis 2: When portion size is maintained, simultaneously reducing the energy density and energy content of pre-portioned entrées will decrease daily energy intake.

Aim 3: To test the effects on daily ratings of hunger and fullness when varying the energy density and energy content of pre-portioned entrées

Hypothesis 3a: Reducing the energy density of entrées will increase daily ratings of fullness.

Hypothesis 3b: Reducing the energy content of entrées will increase daily ratings of hunger.

<u>Study 3: Do variations in the energy density and portion size of the test meal influence satiety assessment?</u>

Incorporation of satiety-enhancing foods into meals is one strategy that could help reduce overconsumption. It is not clear, however, whether the effects of satiety-enhancing foods can be countered by the other foods present at the meal. One way to assess satiety is to use the preloading paradigm, in which a compulsory manipulated preload is served prior to an unmanipulated test meal that is consumed ad libitum. Only a few studies have investigated how the properties of the test meal influence the satiety value of the preload. The current eating environment is filled with large portions of energy-dense foods, which are characteristics that have been shown to influence ad libitum intake. Thus, the purpose of this study was to investigate how variations in the energy density and portion size of the test meal influenced the effects of a satiating preload.

Specific aims and hypotheses for study 3:

Aim 1: To test the effect on energy intake at the test meal of variations in the energy density and portion size of the test meal

Hypothesis 1: Increasing the energy density and portion size of the test meal will independently and additively influence test meal energy intake.

Aim 2: To test the effect of providing a satiating preload on energy intake at the test meal and the total lunch meal (preload + test meal)

Hypothesis 2: Compared to having no preload, consumption of a satiating preload will decrease energy intake at the test meal and the total lunch meal.

Table 1-1. Studies examining the effects of energy density: satiety and satiation studies.

Effects of energy density: satiety studies						
Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Rolls BJ, et al., 1998 (11) N = 20 men	Water Vanilla flavored milk-based drink	300 ml (ED 1.5) 450 ml (ED 1.1) 600 ml (ED 0.8) Equal in energy (499 kcal) & macronutrient content (30.3% fat, 54.7% cho, 15.0% pro) 15 min. to eat (with timer) Control: no preload	Buffet-style meals for lunch & dinner Served 30 min. after preload	Hunger/fullness rated with 100mm VAS Before & after meals & preload and hourly for 3 hr after lunch	Energy intake ↓ at lunch & day (preload + lunch + dinner) with 600 ml vs. 300 ml preload when no preload not included Lunch energy intake ↓ after preload vs. no preload; total lunch (preload + lunch) higher with 300 & 450 ml preload vs. no preload	Greater ↓ hunger with 600 vs. 300 ml preload & greater ↑ fullness after 600 vs. 300 or 450 ml preload
Rolls BJ & Roe LS, 2002 (12) N = 54 women	Water Varied in volume & energy Milk-based preload infused through NG tube	5 conditions: 200 ml/200 kcal (ED 1.0) 400 ml/200 kcal (ED 0.5) 400 ml/400 kcal (ED 1.0) NG but no preload given NG not placed 30% fat, 55% cho, 15% pro Infused over 15 min.	Buffet-style meals for lunch & dinner	Hunger & fullness rated on 100-mm VAS Before & after preload and meals, hourly for 3 hr after lunch	↑ volume (energy constant) ↓ lunch intake but NS effect of ↑ energy content (volume constant) ↓ lunch intake for all preloads vs. no preload NS differences in energy intake at dinner	NS differences in hunger/fullness by preload volume or energy between preload & lunch ↓ hunger & ↑ fullness for 3 preloads vs. control conditions

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Rolls BJ, et al., 1999 (13) N = 24 women	Water Change in form (solid to liquid) and how water included in meal	Chicken rice casserole (ED 1.03) Casserole + 12 oz glass of water (ED 1.03 casserole) Chicken rice soup (12 oz water in soup; ED 0.44) 270 kcal, 33% fat, 50% cho, 17% pro; Consumed in 12 minutes Control: no preload	Buffet-style lunch & dinner	Hunger/fullness rated on 100-mm VAS Before & after meals and preload plus hourly for 4 hour after lunch	All 3 preloads ↓ energy intake at lunch vs. control Soup ↓ energy intake at lunch & preload + lunch more than other preloads NS difference in energy intake at dinner or over the day (preload + lunch + dinner)	Hunger ↓ with soup after preload & before lunch vs. casserole and control Fullness ↑ with soup after preload & before lunch vs. other preloads & control
Mattes R, 2005 (14) N = 31 men & women	Water Varied in form (solid & liquid) and macronutrient content (high-cho/pro/fat)	Apple juice (ED 0.46) Apple soup (ED 0.46) Apple (ED 0.59) Chicken soup (ED 0.45) Chicken breast (ED 1.51) Peanut soup (ED 1.78) Peanuts (ED 5.88) Control: no preload 300 kcal, volume differed Consumed within 10 min.	Diet records completed for rest of the day	Hunger/fullness rated on 9-point category scales Rated every 15 min. for 1 hour post-preload then every 30 min. for 3 hour	Overall effect of food type NS Within high-cho & high-pro conditions, soup ↓ energy intake vs. solid	Soup ↓ hunger & ↑ fullness similar to solids across preload types; within high-cho group, soup & solids similar except soup ↓ fullness vs. solid at 15, 45, 60 min. High-cho beverage led to smaller ↓ in hunger & ↑ in fullness vs. soup or solid

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Rolls BJ, et al., 2004 (15) N = 42 women	↓ fat, ↑ vegetable Salad with dressing	Varied in ED (0.33, 0.67, 1.33) Varied in portion size (150, 300 g) Control: no preload 50-400 kcal, 14-67% fat 20 min. to eat	Pasta (cheese tortellini with tomato sauce) ED 2.0, 700 g 20 min. after salad	100-mm VAS for hunger/fullness before & after preload & after test meal	↑ portion size of salad ↓ energy intake at test meal Total meal energy intake (salad + pasta) ↓ with low-ED salad vs. control but ↑ with high-ED salad vs. control	Fullness ↑ & hunger ↓ after large portion size salads vs. small portion size salads
Gray RW, et al., 2002 (16) N = 20 men	Carbohydrate (maltodextrin, milk, aspartame) Soup preloads	Varied in volume (150, 450 ml) Varied in ED (0.33, 1.00) 3 levels of energy (50, 150, 450 kcal)	Pasta with tomato & onion sauce (ED 1.15, 500 g) 30 min. after soup Food records after test meal for rest of day	Hunger/fullness on 100-mm VAS before/after soup; before/after test meal plus at 50 g intervals during test meal; hourly for 2 hour after test meal + before dinner	Energy intake ↓ after 450 ml/1.00 ED soup vs. other 3 soups NS difference post-lunch or in daily energy intake	↓ hunger & ↑ fullness with 450 ml/0.33 ED soup vs. 150 ml/1.00 ED soup after soup & before pasta ↑ hunger with 450 ml/0.33 ED soup vs. 450 ml/1.00 soup before pasta
Mazlan N, et al., 2006 (17) N = 16 men	Water, fat, carbohydrate Breakfast: porridge Snack: milkshake All compulsory foods: 13% pro, 40% fat, 47% cho	High-ED (1175 kcal, ED 1.91) Low-ED (588 kcal, ED 0.96) 2x-LED (1175 kcal, ED 0.96) Control: no food	15 high-pro, 15 high-fat, 15 high-cho foods Available for the rest of the day	Hunger/fullness measured hourly with 100-mm VAS	Lunch energy intake ↓: 2xLED & HED vs. no food & LED Total daily energy intake (all foods consumed) ↑: 2xLED & HED vs. no food & LED	Hunger ↓ before test lunch: all 3 conditions vs. no food, 2xLED & HED vs. LED Hunger ↓ over day for all 3 conditions vs. no food

Effects of energy density: satiation studies						
Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Stubbs RJ, et al., 1995 (29) N = 6 men	Fat	Various foods provided for 7 days Varied in ED	Low-fat: ED 1.15, 20% fat, 67% cho, 13% pro Medium-fat: ED 1.34, 40% fat, 49% cho, 13% pro High-fat: ED 1.68, 60% fat, 30% cho, 12% pro	Hourly each day with VAS	Daily energy intake ↓ with low-fat/low ED diet Daily energy intake mostly proportional to ED of diet	Fullness ↑ with high-fat/high ED NS differences in hunger
Devitt AA & Mattes RD, 2004 (30) N = 20	Fat	Breakfast, lunch, & dinner (omelets, sandwiches, pizzas)	Varied in ED (low or high) or food unit size (small or customary)	Hunger/fullness measured with 9-point category scale	↑ ED ↑ energy intake independent of food unit size for breakfast, lunch, & daily (all 3 meals)	NS differences
Lissner L, et al., 1987 (31) N = 24 women	Fat (Varied in ED based on fat content)	All foods (20 food items on a rotating menu) provided over a 2 week period	15-20% fat 30-35% fat 45-50% fat ~same % pro, % cho varied	Not measured	Energy intake ↓ as fat content (and ED) ↓ Body wt change reflected energy intake changes	Not measured
Kendall A, et al., 1991 (32) N = 13 women	Fat	All foods (41 food items on a rotating 7-day menu) provided over an 11 week period	Low-fat diet: 20-25% fat vs. Control diet: 35-40% fat	Not measured	Energy intake ↓ with low-fat vs. control diet Wt ↓ with low-fat vs. control diet	Not measured

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Blatt AD, et al., 2011 (27) N = 41 men & women	Vegetables	Entrée varied in ED at all 3 meals + unmanipulated side dishes & evening snack	Standard (100% ED) 85% ED 75% ED % macronutrients held constant	Hunger/fullness rated before & after each meal + at evening snack with 100-mm VAS	Daily energy intake ↓ as ED ↓	Fullness ↑ after breakfast in 75% vs. 100% condition (consistent with intakes)
Chang UJ, et al., 2010 (33) N = 30	Vegetables	Parboiled rice (plain or with radish leaves) at lunch + side dishes Dinner with plain rice + side dishes	Parboiled rice with radish leaves: ED 0.86 Plain parboiled rice: ED 1.42	Hunger/fullness rated with 100-mm VAS before & after meals and hourly for 4 hour after lunch	Energy intake from rice & total lunch ↓ with vegetable rice Energy intake ↓ at dinner with vegetable rice	Fullness ↑ at 2-4 hours post-lunch & hunger ↓ at 3-4 hours post-lunch plus before dinner (both ratings) for vegetable rice vs. plain rice
Bell EA, et al., 1998 (26) N = 18 women	Vegetables, carbohydrate	Ad libitum entrée varied in ED at lunch, dinner, & evening snack (more of lunch entrée); compulsory low-energy side dishes All foods for 2 days	Low-ED: 0.8 Medium-ED: 1.1 High-ED: 1.3 ~22% fat, 59% cho, 19% pro	Hunger/fullness rated before & after meals with 100-mm VAS	Energy intake ↑ for HED vs. MED & LED Similar wt of food consumed across conditions	NS differences
Stubbs RJ, et al., 1998 (28) N = 6 men	Fat, carbohydrate	Various foods provided for 14 days	Diets varied in ED: LED: 0.85 MED: 1.31 HED: 1.76 39-40% fat, 47-48% cho, 13% pro	Hunger/fullness ratings 15 min. after each meal	Average daily energy intakes over 14 days ↓ with LED & MED diets vs. HED diet	Average daily ratings NS different

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Rolls BJ, et al., 1999 (34) N=33 women	Fruit, vegetable, carbohydrate	Various compulsory foods manipulated (providing 50% of subject's average intake at respective meal) at 3 meals/day plus ad libitum side dishes over 4 days	Low-fat/LED: 17% fat, 67% cho, 16% pro, ED 1.05 Low-fat/HED: 16% fat, 67% cho, 16% pro, ED 1.58 High-fat/HED: 37% fat, 48% cho, 16% pro, ED 1.58	Hunger/fullness rated before & after each meal with 100-mm VAS	Energy intake from ad libitum foods ↓ for LED vs. HED (matched for fat) NS differences between HED conditions (fat varied)	NS differences
Duncan KH, et al., 1983 (35) N = 20 men & women	Fat, fruits, vegetables, carbohydrate	Variety of foods provided for 3 meals/day over 5 days	LED meals: 0.7, 7g/1000 kcal fiber, lots of fresh fruits & vegetables, whole grains, dried beans, little fat HED meals: 1.5, 1g/1000 kcal fiber, larger amounts of fat & simple sugars as meats & desserts	Hunger/fullness rated before & after each meal + 3 hours after each meal on a scale of -10 to +10 (-10 extreme hunger, +10 extreme fullness)	Average daily energy intake ↓ for LED vs. HED	↑ hunger before & between meals, ↓ fullness after meals for LED vs. HED
Kral TVE, et al., 2002 (36) N = 40 women	Fruit, vegetables, carbohydrate	3 meals/day Manipulated ED of entrée, low-energy compulsory sides	Varied in ED: 1.25, 1.50, 1.75 25% fat, 60% cho, 15% pro Information vs. no information on ED	Hunger/fullness using 100-mm VAS before & after each meal	↓ entrée ED ↓ daily energy intake (no difference based on ED information)	NS differences

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Bell EA & Rolls BJ, 2001 (37) N = 46 women	Fruits, vegetables, carbohydrates	Entrée at each meal + evening snack varied in ED and % fat (ad libitum), small compulsory portions of LED side dishes at 3 meals	Low-fat: 25% Medium-fat: 35% High-fat: 45% Low-ED: 1.25 High-ED: 1.75 Same % pro, % cho varied with fat	Hunger/fullness using 100-mm VAS before & after each meal	Daily energy intake ↓ for LED vs. HED Similar volume consumed across conditions	Hunger ↓ & fullness ↑ for HED vs. LED (small differences)
Kral TVE, et al., 2004 (38) N = 39 women	Fat, vegetables, carbohydrate	Main entrée varied (ad libitum) + small amount of compulsory sides	Italian pasta bake entrée ED: 1.25, 1.75 Portion size: 500, 700, 900 g 25% fat, 60% cho, 15% pro	Hunger/fullness rated before & after each meal	ED: independent effects on lunch energy intake (↑ as ED ↑)	NS differences
Rolls BJ, et al., 2006 (39) N = 24 women	Fat, fruit, vegetables, carbohydrate Macronutrients varied 75% ED condition (26% fat, 16% pro, 58% cho) 100% ED condition (42% fat, 13% pro, 45% cho)	Variety of foods 3 meals + evening snack for 2 days	Varied in ED: 75%, 100% Varied in portion size: 75%, 100% 3 levels of energy (matched with 75% ED / 100% portion size & 100% ED / 75% portion size	Hunger/fullness measured on 100-mm VAS before & after each meal	ED independently & additively (with portion size) ↓ energy intake over 2 days Energy intake lowest with 75% ED / 100% portion size vs. 100% ED / 75% portion size	NS differences over 2 days

Paper and subjects	ED manipulation	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger & fullness
Cheskin LJ, et al., 2008 (40) N = 54 men & women	Vegetables, protein (Macronutrients varied)	Lunch entrée varied (meat vs. mushrooms) – 4 different entrées; no other foods provided at lunch meal 4 consecutive days	Mean energy of entrées: 783 kcal (meat) & 339 kcal (mushrooms); similar volume served (varied in ED)	Hunger/fullness measured with 100-mm VAS (anchors on same VAS scale)	Energy intake ↓ with mushroom vs. meat entrées	NS differences

Table 1-2. Studies examining the effects of pre-portioned foods on energy intake and hunger/fullness.

Effects of pre-portioned foods on energy intake and hunger/fullness: liquid pre-portioned foods						
Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Wadden TA, et al., 2009 (57) N=5145 men & women	Liquid shakes or bars from SlimFast, Glucerna, Optifast, HMR	2 meals/day (liquid shake), 1 snack/day (bar) for weeks 3-19 1 meal/day plus 1snack/day with liquid shakes and bars for months 7-12	Education on diet, physical activity, & social support	Meal replacement group ↓ more wt at end of 12 months	Not measured	Not measured
Ashley JM, et al., 2001 (58) N=74 women	Group 2: SlimFast meal replacement drinks or bars Drinks: 220 kcal, 7-10 g pro, 40-46 g cho, 1.5-3 g fat, 5 g fiber Bars: 220 kcal, 8 g pro, 33-36 g cho, 5 g fat, 2 g fiber Group 3: Same diet Rx as group 2 + visits with MD & RN	2 meals/day (drinks or bars) Switched to 1 meal/day (drink or bar) if wt loss goal of 10% achieved Free vouchers provided for drinks & bars Rx: 1200 kcal/day	Group 1: Self-selection using USDA Food Guide Pyramid Rx: 1200 kcal/day	Group 2 ↓ more wt at 1 year than other two groups	Not measured	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Ashley JM, et al., 2007 (59) N=70 women	SlimFast meal replacement drinks or bars Drinks: 220 kcal, 7-10 g pro, 40-46 g cho, 1.5-3 g fat, 5 g fiber Bars: 220 kcal, 8 g pro, 33-36 g cho, 5 g fat, 2 g fiber	2 meals/day (drinks or bars) for 12 months Free vouchers provided for drinks & bars Rx: 1200 kcal/day	Self-selection using USDA Food Guide Pyramid Free grocery store certificates ($20/month) Rx: 1200 kcal/day	Mean wt loss NS different between two groups Within both groups was a ↓ in wt from baseline to 1 year	Mean energy intakes ↓ at 1 year but did not differ between groups (~1350-1450 kcal/day); did not achieve goal of 1200 kcal/day	Not measured
Rothacker DQ, 2000 (60) N=141 men & women 906 men & women controls Community-based program	Liquid meal replacements Shakes: 200-220 kcal	2 meals/day for 1st 3 months 1 meal/day until ideal wt achieved (5-year study) During maintenance, 1 meal/day or monitored wt	Did not follow any specific dietary advice Self-reported wt at baseline, wt measured in clinic at 5 years Controls chosen from medical records	Meal replacement group regained wt ↓ at 3 months but wt was below baseline at 5 years Control group ↑ wt at 5 years	Not measured	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Noakes M, et al., 2004 (61) N=55 men & women	SlimFast meal replacement shakes & bars (~430 kcal total) Low-fat evening meal, at least 5 servings F&V (~830 kcal total)	2 meals/day Stage 1 (3 months), Stage 2 (+3 months) Rx: ~1400 kcal/day	Low-kcal/low-fat diet Rx: ~1400 kcal/day	No differences in wt loss between groups at baseline or 3 or 6 months Both groups ↓ wt from baseline at 3 & 6 months	No difference in energy intake between groups at 3 or 6 months	Not measured
Leader N, et al., 2013 (62) N = 36 men & women	Optifast shakes	2 groups: 1 meal/day vs. 2 meals/day for 12 months	None	At 3 months, both groups ↓ wt than baseline At 1 year, 2 meals/day group had ↓ wt than 1 meal/day group	Not measured	Not measured
Metzner CE, et al., 2011 (63) N = 87 women	FormMed HealthCare meal replacements (shakes, soups & bars) Per serving: 200-218 kcal	2 meals/day (breakfast + lunch) with 2 shakes, soups, or bars & eat own lunch Rx: 1200 kcal/day 12 weeks	3 meals with F&V, whole grain cereal, low-fat dairy Rx: 1200 kcal/day, 12-20% pro, 50-55% cho, 30% fat 12 weeks	NS difference in wt loss at 12 weeks (both groups ↓ wt) ≥ 5% wt loss ↑ in meal replacement vs. control group	NS difference in energy intake at 12 weeks (both groups ↓ energy intake)	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Ditschuneit HH, et al., 1999 (64) N=100 men & women (Phase 1); 63 men & women (Phase 2) Flechtner-Mors M, et al., 2000 (65) N=75 men & women	SlimFast shakes, soups, or hot chocolate & nutrition snack bars Shakes/soups/hot chocolate: 200-250 kcal, 14-17 g pro, 27-33.5 g cho, 5-6.6 g fat, 4.5-6.5 g fiber Bars: 90-110 kcal, 1.4-1.7 g pro, 16.1-18.1 g cho, 2.4-3.9 g fat, 1.1 g fiber Rx: 1200-1500 kcal/day, 19-21% pro, 48-54% cho, 25-34% fat	Phase 1: 2 meals/day + 2 snacks/day for 3 months Phase 2: 1 meal/day + 1 snack/day for 48 months	Phase 1: Self-selected, conventional foods for 3 meals + 2 snacks for 3 months Phase 2: 1 meal/day + 1 snack/day as meal replacements for 48 months Rx: 1200-1500 kcal/day, 19-21% pro, 48-54% cho, 25-34% fat	Phase 1: Both groups ↓ wt at 3 months; % wt change greater in meal replacement group at 3 months Phase 2: Both groups ↓ wt at 27 months; meal replacement group ↓ & maintained more wt at 27 months At 51 months, both groups had ↓ wt from baseline; % wt loss from baseline was ↑ in meal replacement group due to 1st 3 months	Phase 1: NS difference between groups; ↓ in energy intake in men in meal replacement group at 3 months Phase 2: NS difference between groups at 27 months	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Rothacker DQ, et al., 2001 (66) N=64 women (completers)	Milk-based shakes (powder mixed with skim milk) Shakes: 220 kcal, 15-19 g pro, 1.5 g fat, 5 g fiber	1-3 meals/day for 12 months Rx: low-energy, low-fat diet, 1200 kcal/day, ~55% cho, 15% pro, & < 30% fat	Rx: low-energy, low-fat diet, 1200 kcal/day, ~55% cho, 15% pro, & < 30% fat for 12 months	↓ in wt in both groups at 3 months; meal replacement group maintained wt loss at 12 months & wt was different than control group (regained wt)	Not measured	Not measured
Cheskin LJ, et al., 2008 (67) N = 112 men & women	Portion-controlled diet (PCD) – Medifast Plus for Diabetics meal replacements (bars, shakes, soups) 45-50% cho, 25-30% fat, 15-25% pro Rx: 25% energy-deficit	50-60% energy needs from meal replacements 34 week wt loss phase + 52 week maintenance phase (26 weeks PCD + 26 weeks SD vs. 26 weeks SD + 26 weeks PCD	Standard diet (SD) Rx: 25% energy-deficit with ADA recommendations 45-50% cho, 25-30% fat, 15-25% pro 34 week wt loss phase + 52 week maintenance phase (same diet)	↑ Wt loss at 34, 60, & 86 weeks in PCD vs. SD (intention-to-treat) Similar findings with ITT & completers	Not measured	Not measured

Effects of pre-portioned foods on energy intake and hunger/fullness: comparing liquid & solid pre-portioned foods						
Paper and subjects	**Solid test food**	**Liquid test food**	**Discretionary food**	**Hunger & fullness measurements**	**Effects on energy intake**	**Effects on hunger/fullness**
Stull AJ, et al., 2008 (68) N=24 men & women	Solid meal replacement (Ensure Cinnamon Oat'n Raisin nutrition & energy bar) Provided 25% EER; ~2-2.5 servings consumed	Liquid meal replacement (vanilla Ensure Complete Balanced Nutrition beverage) Provided 25% EER; ~2-2.5 servings consumed	Oatmeal Received 120 minutes after meal replacement	Rated hunger & fullness on 100 mm VAS at 15, 30, 45, 60, 90, 120 after meal replacement, 30 min after oatmeal	Consumed 13% more oatmeal after liquid vs. solid meal replacement	NS differences in hunger/fullness at 150 min post-meal replacement Hunger AUC ↑ for liquid vs. solid meal replacement; NS difference in fullness AUC
Tieken SM, et al., 2007 (69) N=9	Solid meal replacement (SlimFast Original bar) Provided 25% EER; ~2.5 servings consumed	Liquid meal replacement (SlimFast shake) Provided 25% EER; ~2.5 servings consumed	None provided	Rated hunger & fullness using VAS at 15, 60, 120, 180, 240 min after meal replacement	Not measured	Hunger AUC ↓ for solid vs. liquid meal replacement; NS differences in fullness

Effects of pre-portioned foods on energy intake and hunger/fullness: solid pre-portioned foods

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Davis LM, et al., 2010 (70) N=90 men & women (48 at week 16, 46 at week 40)	Medifast 5&1 Plan Meal replacements each 90-100 kcal, low-fat, low-GI, low sugar, & soy or whey protein-based Plus 5-7 oz lean protein, 1.5 cups non-starchy vegetables, 2 fat servings	5 meal replacements/day (16-week wt loss phase) 3-5 meal replacements/day (24-week wt maintenance phase) Rx: 800-1000 kcal/day	Isocaloric food-based plan using USDA Food Guide Pyramid 3 oz grains, 1 cup each F&V, 1 cup milk, 5-7 oz lean protein, 3 tsp of fat Rx: 800-1000 kcal/day	Meal replacement group ↓ more wt at 16 & 40 weeks than control group	Not measured	NS differences between groups
Shikany JM, et al., 2013 (71) N = 95 men & women	Medifast 5&1 Plan (70 meal choices) ‘Lean & Green’ meal: 5-7 oz lean protein + 0-2 servings healthy fat + 3 servings low-cho/non-starchy vegetables (0.5-1 c)	26 week wt loss: 5 meals/day + 1 ‘Lean & Green’ meal/day Medifast meals provided ~800-1000 kcal/day 26 week wt maintenance: 0-3 meals/day	Referred to MyPyramid.gov website for info. Rx: 1000 kcal/day 26 week wt loss, 26 week wt maintenance	Meal replacement group ↓ wt more than control group at 26 & 52 weeks	Not measured	NS differences in hunger/fullness between groups at 26 & 52 weeks

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Hannum SM, et al., 2004 (72) N=53 women	Uncle Ben’s bowls (portion-controlled entrées) – 24 options Rx: ~1365 kcal, 55% cho, 25% pro, 20% fat 2 categories (ate 1 from each category daily): average daily intake with 2 entrées was ~730 kcal, 12.5 g fat, 43.4 g pro, 113.4 g cho	2 meals/day (lunch & dinner) + 2 cups salad vegetables, 2 cups nonfat milk or yogurt, 2 servings fruit, 3 servings whole grains Consumed entrées for 8 weeks	Self-selected diet based on Food Guide Pyramid: 2 servings meat group, 2 servings non-fat dairy, 2 servings fruit, 3 servings vegetable, 6 servings grains Rx: ~1365 kcal, 55% cho, 25% pro, 20% fat	Portion-controlled entrées group ↓ more wt than control group but both groups ↓ wt over 8 weeks	NS different between groups; both groups ↓ energy intake	Not measured
Hannum SM, et al., 2006 (73) N=51 men	Uncle Ben’s bowls (portion-controlled entrées) – 24 options Rx: ~1700 kcal, 55% cho, 25% pro, 20% fat 2 categories of bowls (ate 1 from each category daily): average daily intake with 2 entrées was ~730 kcal, 12.5 g fat, 43.4 g pro, 113.4 g cho	2 meals/day (lunch & dinner) plus 1 serving meat, 2.5 cups salad vegetables, 2 cups nonfat milk or yogurt, 3 servings fruit, 4 servings whole grains, 8 cups water daily Consumed entrées for 8 weeks	Self-selected diet based on Food Guide Pyramid: 3 servings meat group, 2 servings non-fat dairy, 3 servings fruit, 4 servings vegetable, 7 servings grains, 8 cups water daily Rx: ~1700 kcal, 55% cho, 25% pro, 20% fat	Portion-controlled entrées group ↓ more wt than control group but both groups ↓ wt over 8 weeks	NS different between groups; both groups ↓ energy intake	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Metz JA, et al., 2000 (74) N=302 men & women	Prepared meal plan (7 breakfast, 13 lunch, 12 dinner, & 8 snack options) Rx: 22% fat, 58% cho, 20% pro 2 groups based on comorbidities 1 year study	1 prepared meal for 3 meals/day plus 1 serving each F&V, low-fat dairy Snacks used to adjust intake 1 item from a “bonus list” (100 kcal) of vegetable oils, alcohol, fruit, vegetables, or low-fat dairy	Usual care diet Fixed number of servings from ADA & ADA exchange lists plus 1 item from “bonus list” Rx: 22% fat, 58% cho, 20% pro 2 groups based on comorbidities	Prepared meal plan groups ↓ more wt than usual care groups (at 12, 26, & 52 weeks)	NS differences in energy intake across groups during study period	Not measured
Metz JA, et al., 1997 (75) N=560 men & women	Prepared meals by Campbell Soup Company (6 breakfast, 8 lunch, 10 dinner, & 6 snack selections) Rx: 15-20% fat, 55-60% cho, 15-20% pro	1 prepared meal for 3 meals/day plus 1 serving each F&V, low-fat dairy Snacks used to adjust intake 10 weeks	Self-selected diet group Fixed number of servings from American Dietetic Association & American Diabetes Association exchange lists 10 weeks Rx: 15-20% fat, 55-60% cho, 15-20% pro	↑ wt loss for prepared meal group compared to self-selected diet group In both groups, dietary compliance related to ↑wt loss	Both groups ↓ energy intake over 10 weeks Prepared meal plan group more compliant with dietary goals	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Pi-Sunyer FX, et al., 1999 (76) N=202 men & women	Campbell's Center for Nutrition & Wellness meal program (6 breakfast, 8 lunch, 10 dinner, & 6 snack selections) Rx: 55-60% cho, 15-20% pro, 20-30% fat	1 prepared meal for 3 meals/day plus 1 serving each F&V, low-fat dairy Snacks used to adjust intake 10-week intervention	Self-selected diet Fixed number of servings from ADA & ADA exchange lists 10-week intervention Rx: 55-60% cho, 15-20% pro, 20-30% fat	↓ in wt in both groups during treatment NS differences in wt after intervention between groups In prepared meal group the % achieving wt loss goals was greater	↓ energy intake during treatment in both groups NS differences in energy intake between groups after intervention	Not measured
Vander wal JS, et al., 2007 (77) N = 133 men & women	Special K products (ready-to-eat cereal, nutrient bar, waffle) Cereal substitution + Nutrient bar (CB); Cereal & waffle substitution + Nutrient bar (CWB); Cereal substitution, no Nutrient bar (CR) Followed diet for 4 weeks	CB: 1 serving cereal + skim milk & fruit for 2 meals/day (breakfast & lunch/dinner), 3rd meal usual diet, + nutrition bar for snack CWB: Same as CB except to replace 1 of 2 cereal meals with waffle + light syrup CR: Same as CB except no nutrition bar offered All groups could eat F&V for snacks	Control (CN) – follow normal dietary routines – told entry into study was allowed after 4 weeks	CB, CWB, & CR groups ↓ wt more than CN group at 4 weeks NS differences in ↓ wt at 4 weeks for CB, CWB, & CR groups	Not measured	NS changes in hunger across groups

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Webber KH & Rose SA, 2013 (78) N = 50 men & women	Internet + portion-controlled diet (PCD) – Nutrisystem Entrées & snacks 12 weeks	3 entrées + 1-2 snacks per day Supplemented with F&V + dairy Rx: ~1200 kcal/day (women), 1500 kcal/day (men)	Internet-based behavior therapy alone Rx: ~1200 kcal/day (women), 1500 kcal/day (men) 12 weeks	NS differences in wt loss at 12 weeks between groups	Not measured	Not measured
McCarron DA, et al., 1997 (79) N = 560 men & women	Campbell's Center for Nutrition & Wellness (CCNW) plan [6 breakfast, 8 lunch, 10 dinner, 6 snack options]	3 meals/day + F&V, low-fat dairy, 1 pick from bonus list 10 weeks Rx: 17% fat, 62% cho, 21% pro	AHA Step 1 & Step 2 diet + ADA exchange lists 10 weeks Rx: 17% fat, 62% cho, 21% pro	CCNW ↓ wt more than control group at 10 weeks	Energy intake ↓ in both groups vs. baseline but ↓ in control > CCNW (based on 3-day diet records	Not measured
Anderson JW, et al., 2011 (80) N = 38 men & women	HMR Program (shelf-stable entrées, shakes – could purchase bars & extra meals) = Healthy Solutions Option Low-energy diet (≥1200 kcal/day)	Daily minimum of 2 entrées, 3 shakes + 5 servings F&V 24 week study	Energy-restricted diet with 30% fat, 50% cho, 20% pro	↑ wt loss at 8, 16, & 24 weeks in healthy solutions group vs. control	Not measured	Not measured

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Foster GD, et al., 2013 (81) N = 100 men & women	Nutrisystem (pre-packaged – PCD) Rx: 1250 kcal/day (women) & 1550 kcal/day (men); 50-55% cho, 20-25% fat, 20-25% pro	3 entrées & 1 snack daily + F&V, dairy items, lean protein ~55% energy from pre-packaged foods 6 months	ADA National Standards for DSME Rx: 1250 kcal/day (women) & 1550 kcal/day (men); 15-25% pro, <30% fat (<7% saturated fat), & rest cho, 30 g fiber	↑ wt loss at 6 months for PCD group vs. DSME group	Not measured	Not measured
Mattes RD, 2002 (82) N=133 men & women	2 pre-portioned food groups: Ready-to-eat cereal (Special K or a variety of brands) + 2/3 cup skim milk & 100 kcal portion of fruit with cereal No restrictions on no cereal meal -500 kcal/day of EER	2 meals/day 2 weeks Received Volumetrics book for 4 weeks 6 weeks total	2 control groups: Non-diet control: no diet instruction Diet control: received Volumetrics book (emphasizes low-ED foods) for 4 weeks (nothing the first 2 weeks) -500 kcal/day of EER	Compared to baseline Special K & variety groups ↓ wt and ↓ wt vs. either control group at 2 weeks Special K & variety group ↓ wt vs. non-diet control after 6 weeks and Special K vs. diet control after 6 weeks	Similar ↓ in energy intake for Special K & variety groups, both ↑ than non-diet control during 1st 2 weeks Special K, variety, & diet control groups had similar ↓ in energy intake during Volumetric phase & all were ↓ vs. non-diet control group	NS difference in fullness ratings ↑ hunger ratings during cereal phase compared to baseline & Volumetric phase

Paper and subjects	Pre-portioned food group	Frequency of meal replacement consumption	Control group	Effects on weight loss	Effects on energy intake	Effects on hunger/fullness
Rock CL, et al., 2010 (83) N = 442 women	Jenny Craig pre-packaged foods: 2 groups: center-based or telephone-based Total trial: 2 years Rx: 1200-2000 kcal/day, 20-30% fat + increased F&V, cereal/grains, low-fat dairy, lean protein	Wt loss phase: Multiple meals - Prepackaged foods provided 42-68% daily energy Wt loss maintenance phase: no more than 1 prepackaged meal/day	Usual care Rx: -500-1000 kcal/day for wt loss, publicly available print material for dietary advice Total trial: 2 years	Both pre-packaged foods groups ↓ wt compared to usual care at 24 months	Not measured	Not measured
Kreider RB, et al., 2011 (84) N = 90 women (wt loss trial); 77 women (wt maintenance phase)	Special K (SK) Challenge Program [SK ready-to-eat (RTE) cereal + cereal bars] + encouraged to ↑ physical activity	Phase 1 (2 weeks): 2 meals/day SK ready-to-eat cereal + 2/3 c skim milk + fruit, 3rd meal as usual + F&V as snacks Phase 2 (8 weeks): -500 kcal/day + SK breakfast (phase 1), SK cereal bars, F&V as snacks Phase 3 (24 weeks): Wt maintenance, SK cereal & cereal bars as needed	Curves diet program (SDE) with exercise Phase 1 (1 week): 1200 kcal/day Phase 2 (9 weeks): 1600 kcal/day Phase 3 (24 weeks): 2100 kcal/day with 1200 kcal/day if wt gain ≥ 3 lbs All phases: 45% cho, 30% pro, 25% pro + RTE cereals for ≥ 4 breakfasts/week, snack bars ≥ 3x's/week	SDE ↓ wt more than SK at 10 & 34 weeks	Both groups ↓ energy intake at 10 & 34 weeks vs. baseline; NS differences between groups	NS differences in hunger/fullness at 10 & 34 weeks

Table 1-3. Studies examining the effects of various food characteristics on energy intake and hunger/fullness.

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Gray RW, et al., 2002 (16) N = 20 men	Varied in volume (150, 450 ml) Varied in ED (0.33, 1.00) 3 levels of energy (50, 150, 450 kcal) Soup preloads: reduced in ED with carbohydrate (maltodextrin, milk, aspartame)	Pasta with tomato & onion sauce (ED 1.15, 500 g) 30 min. after soup Food records after test meal for rest of day	Hunger/fullness on 100-mm VAS before/after soup; before/after test meal plus at 50 g intervals during test meal; hourly for 2 hour after test meal + before dinner	Energy intake at test meal ↓ after 450 ml/1.00 ED soup vs. other 3 soups NS difference post-lunch or in daily energy intake	↓ hunger & ↑ fullness with 450 ml/0.33 ED soup vs. 150 ml/1.00 ED soup after soup & before pasta ↑ hunger with 450 ml/0.33 ED soup vs. 450 ml/1.00 soup before pasta
De Graaf, et al., 1996 (85) N = 37 men & women	9 preloads 3 weights: 250, 500, 750 g (volume varied) 3 energy levels: 0, 300, 600 kcal 0 kcal preloads were tap water; others were yogurt + added fat, cho, or pro Consumed in 5-6 min. on average	Buffet with sweet & savory snacks, sweet desserts, fruits, & drinks served 2 hours after preload Food diary for the remainder of the day	150-mm scales; ratings made before & after preload (15 min. after 1st rating) & 45, 60, 90, & 120 min. after 1st rating	300 & 600 kcal ↓ at test meal vs. 0 kcal 600 kcal ↑ at test meal + preload vs. 300 & 0 kcal 500 & 750 g ↓ intake at test meal vs. 250 g (smaller effect than energy content)	Hunger ↑ after 15 min. for 0 kcal vs. other preloads; hunger ↑ for 300 vs. 600 kcal at 120 min. Hunger ↓ as weight increased

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Gray R, et al., 2003 (86) N = 18 men	Varied in volume (150, 450 ml) Varied in ED (0.33, 1.00) 3 levels of energy (50, 150, 450 kcal) Soup preloads: reduced in ED with carbohydrate (maltodextrin, milk, aspartame)	Pasta with tomato & onion sauce (ED 1.15, 500 g) Served immediately after soup (no delay) Food records after test meal for rest of day	Hunger/fullness on 100-mm VAS before/after soup; before/after test meal plus at 50 g intervals during test meal; hourly for 2 hour after test meal	Energy intake at test meal ↓ after 450 ml/1.00 ED soup vs. other 3 soups Energy intake at lunch (preload + test meal) ↑ after 450 ml/1.00 ED soup vs. 3 other soups	Before soup & after pasta, hunger ↓ & fullness ↑ with high vs. low volume of soup (energy matched) NS effect on hunger with low vs. high energy soup (volume matched)
Yeomans MR, et al., 2001 (87) N = 24 men	Low (63 kcal) or high (360 kcal) energy soup preloads (3 versions) High-energy preloads were either high-fat or high-cho (1/2 of subjects got each type of high-energy preload)	Bland or Palatable test meal Pasta with unseasoned (bland) or seasoned (palatable) tomato & onion sauce 30 min. after preload 500 g served	100-mm VAS for hunger & fullness Interrupted after every 50 g eaten; food replenished after 6th interruption Weighed food diary for remainder of day	Energy intake at test meal ↓ with high vs. low energy preload (NS differences for high-fat/cho preloads) Total energy (preload + test meal) ↑with high vs. low energy preloads NS differences in food intake after test meal but daily energy intake ↑after high-energy preloads	High- vs. low-energy preload ↓ hunger & ↑ fullness before test meal (both cho & fat) NS differences in hunger/fullness after test meal 2 hours after test meal, hunger ↓ with high vs. low energy preloads

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Wiessing KR, et al., 2012 (88) N = 29 men	Low- (120 kcal) or high-energy (955 kcal) breakfast preloads Eaten within 15 min. Low-energy: hazelnut & vanilla yogurt High-energy: muesli, milk, toast, jam, butter, banana	Restricted item or multi-item test meal Restricted: pasta + meat sauce Multi-item: pasta + meat sauce, bread, chicken, ham, cheese, salad items, cake, peaches, condiments Served 3 hours after preload	VAS used to rate hunger & fullness Measured between preload & test meal (15-30 min. intervals) and 2 hours post-test meal (30 min. intervals)	↑ energy content of preload ↓ energy intake at test meal	High-energy preload led to ↓ hunger & ↑ fullness between preload & test meal; NS differences after test meal
Mazlan N, et al., 2006 (17) N = 16 men	Breakfast: porridge Snack: milkshake High-ED (1175 kcal, 613 g, ED 1.91) Low-ED (588 kcal, 613 g, ED 0.96) 2x-LED (1175 kcal, 1226 g, ED 0.96) Control: no food All 13% pro, 40% fat, 47% cho	15 high-pro, 15 high-fat, 15 high-cho foods Available for the rest of the day	Hunger/fullness measured hourly with 100-mm VAS	Lunch energy intake ↓: 2xLED & HED vs. no food & LED Total daily energy intake (all foods consumed) ↑: 2xLED & HED vs. no food & LED	Hunger ↓ before test lunch: all 3 conditions vs. no food, 2xLED & HED vs. LED Hunger ↓ over day for all 3 conditions vs. no food

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Poortvliet PC, et al., 2007 (89) N = 13 men	Compulsory main course: 500 kcal Healthy meal (chicken stir-fry; 1.25 ED) vs. Control (fettuccini carbonara; 2.7 ED) Healthy meal: low-fat, high-pro, high-fiber, low-ED, large volume, capsaicin Consumed within 30 min.	Dessert (2nd course), ad libitum, served 10 min. after main course Chocolate mousse cake Food diary for remainder of the day	150-mm VAS for hunger & fullness before & after main course + dessert + every 30 min. for 3 hrs after 2nd course	Energy intake ↓ at 2nd course and after meal (main course + 2nd course) for healthy vs. control meal	Hunger ↓ & fullness ↑ after main course for healthy vs. control meal Hunger ↓ for 3 hrs after lunch for healthy vs. control meal
Kirkmeyer SV & Mattes RD, 2000 (90) N = 24 men & women	8 preloads, 500 kcal amounts of peanuts, peanut butter, almonds, chestnuts, chocolate; pickles were wt-matched to peanuts; rice cakes were volume-matched to peanuts; no preload Varied in attributes including weight, volume, energy density, energy, macronutrients; consumed in 15 min.	Food diary for 24 hours	13-point category scale for hunger Baseline and 180 min. post-preload	NS difference over day across preloads	Hunger AUC ratings ↓ after peanuts, peanut butter, almonds, chestnuts & chocolate vs. pickles, rice cakes, no preload

Table 1-4. Studies examining the effects of variations in the test meal on energy intake and hunger/fullness.

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Wiessing KR, et al., 2012 (88) N = 29 men	Low- (120 kcal) or high-energy (955 kcal) breakfast preloads; Eaten within 15 min. Low-energy: hazelnut & vanilla yogurt High-energy: muesli, milk, toast, jam, butter, banana	Restricted: pasta + meat sauce Multi-item: pasta + meat sauce, bread, chicken, ham, cheese, salad items, cake, peaches, condiments Served 3 hours after preload	VAS used to rate hunger & fullness Measured between preload & test meal (15-30 min. intervals) and 2 hours post-test meal (30 min. intervals)	↑ energy content of preload ↓ energy intake at test meal Energy intake ↑ at multi-item vs. restricted test meal (independent of preload energy)	NS differences after test meal
Long SJ, et al., 2001 Abstract (97) N = 14 men & women	High (599 kcal) & low (240 kcal) energy preloads Flavored milkshakes 450 ml each	Single item test meal (pasta) vs. buffet-style test meal Same energy & % macronutrients in test meals 60 min. after preload	Hunger/fullness rated before & after preload & every 20 min. for 1 hour post-preload	Energy intake with single item ↓ buffet for high-energy preload Energy intake ↓ for high- vs. low-energy preload	NS differences in hunger/fullness
Norton GNM, et al., 2006 (98) N=30 men & women	Tomato soup (compulsory) Varied in volume (2 levels) by amount of water – sex-specific Men: 300 vs. 600 ml; Women: 240 vs. 480 ml Soups differed in ED Consumed over 15 min, paced with a stopwatch	Sandwiches served 30 min after soup (ad libitum) Varied in variety of filling type (2 levels) 2nd preferred filling vs. 2nd, 3rd, & 4th preferred filling Single filling: Men = 24 quarters, Women = 18 Variety fillings: Men = 8 quarters each filling; Women = 6 quarters	Hunger & fullness VAS pre- & post-soup and pre- & post-sandwiches	Soup volume had NS effect on intake of sandwiches Energy intake ↑ in variety condition vs. single filling (14% increase with variety)	Hunger ↓ with high vs. low volume soup Fullness ↑ with high vs. low volume

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Lawton CL, et al., 1993 (99) N=12 women	Compulsory meal at midday varying in energy Low energy: 527 kcal, 15.7% pro, 51.2% cho, 33% fat High energy: 985 kcal, 15% pro, 49.8% cho, 35.2% fat Received 1 of 2 energy levels twice	Ad libitum dinner test meal with a range of either high-cho or high-fat foods High-fat meal: 7 foods with at least 50% fat High-cho meal: 7 foods with at least 50% cho & no more than 25% fat Received both test meals	Hunger rated with 150-mm VAS at midday meal & 1,2,3 hours after midday meal Hunger rated at dinner test meal every 15 min for 1 hr from start of meal All food recorded for remainder of day & following 24 hours	Energy intake at test meal ↑ at high-fat vs. high-cho meal (NS difference in wt of test meal eaten) Total daily food intake (including midday meal & test meal) ↑ with high-fat vs. high-cho meal	Hunger ↑ after low energy midday meal at 2,3,& 4 hr post-meal NS difference in ratings of filling after test meal
Yeomans MR, et al., 2001 (87) N = 24 men	Low (63 kcal) or high (360 kcal) energy soup preloads (3 versions) High-energy preloads were either high-fat or high-cho (1/2 of subjects got each type of high-energy preload)	Bland or Palatable test meal Pasta with unseasoned (bland) or seasoned (palatable) tomato & onion sauce 30 min. after preload 500 g served	100-mm VAS for hunger & fullness Interrupted after every 50 g eaten; food replenished after 6th interruption Weighed food diary for remainder of day	Energy intake at test meal ↓ with bland vs. palatable test meal and (NS differences for high-fat/cho preloads)	NS differences in hunger/fullness after test meal 2 hours after test meal, hunger ↓ with high vs. low energy preloads

Paper and subjects	Preload	Test food	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Robinson TM, et al., 2005 (100) N = 21 men	Intragastric infusion of low- or high-energy soup preload (300 ml) ½ subjects, high-energy was high-cho; ½ subjects, high-energy was high-fat Low energy: 63 kcal High-energy: ~360 kcal (both high-fat & high-cho)	Palatable or Bland lunch test meal (served 30 min after preload) Pasta shells with unseasoned (bland) or seasoned (palatable) tomato & onion sauce (1.15 kcal/g) 500 g portion served Bowl refilled after 300 g consumed	Hunger & fullness ratings completed during test meal (prompted by computer at 50 g intervals) Hunger & fullness ratings measured 1 & 2 hours after test meal & before evening meal	High-cho preload ↓ intake in bland & palatable test meals; High-fat preload did NS reduce test meal intakes Energy intake ↑ with palatable vs. bland conditions after high-fat preload Total energy (preload + test meal) ↑ after high-energy vs. low-energy preloads	High-energy preloads ↓ hunger & ↑ fullness after preload & test meal compared to low-energy preloads Greater ↓ in hunger with high-cho vs. high-fat preload Effects on hunger/fullness varied by fat/cho content of preload NS differences in hunger/fullness 2 hr after test meal

Table 1-5. Studies examining the effects of portion size on energy intake and hunger/fullness.

Paper and subjects	Foods	Manipulation	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Rolls BJ, et al., 2002 (24) N = 51 men & women	Lunch entrée varied (ad libitum); unvaried sides (compulsory) 2 groups: served on a plate or in a serving dish	Macaroni & cheese entrée: 500, 625, 750, 1000 g portions	Hunger/fullness rated before & after lunch with 100-mm VAS	Energy intake ↑ as portion size of entrée ↑ (all portions different from one another except 625 & 750 g) NS differences by how entrée served	NS differences
Kral TVE, et al., 2004 (38) N = 39 women	Main entrée varied (ad libitum) + small amount of compulsory sides	Italian pasta bake entrée ED: 1.25, 1.75 Portion size: 500, 700, 900 g 25% fat, 60% cho, 15% pro	Hunger/fullness rated before & after each meal	Portion size: independent effects on lunch energy intake (↑ as portion size ↑)	NS differences
Rolls BJ, et al., 2006 (39) N = 24 women	Variety of foods 3 meals + evening snack for 2 days	Varied in ED: 75%, 100% Varied in portion size: 75%, 100% 3 levels of energy (matched with 75% ED / 100% portion size & 100% ED / 75% portion size	Hunger/fullness measured on 100-mm VAS before & after each meal	Portion size independently & additively (with ED) ↓ energy intake over 2 days Energy intake lowest with 75% ED / 100% portion size vs. 100% ED / 75% portion size	NS differences over 2 days
Rolls BJ, et al., 2004 (101) N = 75 men & women	Main item varied (ad libitum); unvaried sides (compulsory)	Deli-style sandwich: 6, 8, 10, 12 inches Proportions of ingredients the same (ED 2.4)	Hunger/fullness rated before & after lunch with 100-mm VAS	Energy intake ↑ as portion size of sandwich ↑ Men: ↑ all portions; Women: 8 & 10 in portions NS different	After lunch, hunger ↑ & fullness ↓ after 6 in versus 3 other portions; NS differences between 3 other portions for hunger or fullness

Paper and subjects	Foods	Manipulation	Hunger/fullness measurements	Effects on energy intake	Effects on hunger/fullness
Dilberti N, et al., 2004 (102) N = 180 men & women	Baked pasta entrée in a cafeteria setting (varied) served with side vegetable & roll (unvaried)	Standard (100%), 150% 27% cho, 19% pro, 54% fat, ED 1.7	Not measured	Energy intake of entrée ↑ with 150% vs. 100% portion (+ ate more of sides) Same for total lunch	Not measured
Rolls BJ, et al., 2006 (103) N = 32 men & women	All foods for meals & snacks for 2 days	Baseline (100%), 150%, 200% Women's portions 25% of men's for entrée & dessert items; same for all other foods & beverages	Hunger & fullness rated before & after each meal with 100-mm VAS	Daily energy intake ↑ as portion size increased (for both 150 & 200% portion sizes) & was sustained over 2 days	Hunger ratings ↑ and fullness ratings ↓ with 100% portions vs. 150 & 200% portion sizes; NS differences between 150 & 200%
Kelly MT, et al., 2009 (104) N = 43 men & women	All foods for meals & snacks for 4 days	Portion sizes: Standard (smallest pre-portioned units available) or Large (units of the same foods designed to serve ≥ 2 people	Hunger/fullness rated before & after each meal using 100-mm VAS	Energy intake ↑ over 4 days for large vs. standard portions Wt ↑ over 4 days for large vs. standard portions	After meals, hunger ↓ for large vs. standard portions NS differences in daily ratings of hunger & fullness for large vs. standard portions
Rolls BJ, et al., 2007 (105) N = 23 men & women	All foods for meals & snacks for 11 days	Baseline (100%), (150%) Women's portions 25% of men's at main meals; same for snacks & beverages	Hunger & fullness rated before & after each meal with 100-mm VAS	Daily energy intake ↑ with 150% portions	Daily AUC fullness ↑ and hunger ↓ with 150% portions

Paper and subjects	Foods	Manipulation	Hunger/Fullness Measurements	Effects on energy intake	Effects on hunger/fullness
Flood JE, et al., 2006 (106) N = 33 men & women	Beverage at lunch varied At lunch, all foods + beverage consumed ad libitum	Pepsi, diet Pepsi, or water Varied in portion size (360 g/12 oz vs. 540 g/18 oz)	Hunger/fullness rated using 100-mm VAS before & after lunch	(Weight of beverage ↑ as portion ↑) Energy intake of beverage ↑ when portion size ↑; total meal energy intake (food + beverage) ↑ with caloric beverage	NS differences
Rolls BJ, et al., 2004 (107) N = 60 men & women	Snack varied	Potato chips: 28, 42, 85, 128, 170 g portions Ad libitum dinner eaten in lab; provided 64% cho, 25% fat, 11% pro	Hunger/fullness rated before & after snack, 1 & 2 hours after snack, & before & after dinner using 100-mm VAS	Energy intake ↑ as portion size ↑ (in men, NS different between 2 largest portions; in women, NS different between 3 largest portions Combined intake (snack + dinner) was greater for both sexes as snack portion size ↑	Between snack & dinner, hunger ratings ↓ with increasing package size & fullness ratings ↑ with increasing package size

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CHAPTER 2

Study 1:

Comparison of three methods to reduce energy density: effects on daily energy intake

Williams RA, Roe LS, Rolls BJ. Comparison of three methods to reduce energy density: effects on daily energy intake. *Appetite* 2013;66:75-83.

INTRODUCTION

Given the current rates of obesity, it is critical to determine dietary approaches that can moderate the over-consumption of energy. One strategy that has been promoted by government and health organizations is to reduce dietary energy density (ED; kcal/g or kJ/g), because reductions in ED have robust effects on energy intake (Division of Nutrition, Physical Activity and Obesity, 2008; Pérez-Escamilla et al., 2012). Several different methods can be used to reduce ED including decreasing the fat content, increasing the proportion of fruit and vegetables, adding water, and using sugar or fat substitutes; all of these methods have been shown to decrease energy intake (Blatt, Roe, & Rolls, 2011a; Duncan, Bacon, & Weinsier, 1983; Hill et al., 1998; Lissner, Levitsky, Strupp, Kalwarf, & Roe, 1987; Rolls, Hetherington, & Laster, 1988; Rolls, Bell, & Thorwart, 1999a). Previous studies of reductions in ED, however, have not determined whether these methods differ in their effects on intake. The purpose of the current study was to compare three methods commonly used to reduce ED (decreasing fat, increasing fruit and vegetables, and adding water) in order to determine whether they have different effects on daily energy intake and at individual eating occasions over a day.

The impact that ED has on energy intake can be influenced by a variety of factors. On the one hand, numerous studies show that people tend to eat a consistent weight or volume of food when ED is varied (Bell, Castellanos, Pelkman, Thorwart, & Rolls, 1998; Blatt et al., 2011a; Stubbs, Johnstone, O'Reilly, Barton, & Reid, 1998). On the other hand, since food intake results from a complex interplay of a number of factors, this tendency to eat a consistent amount can be affected by food characteristics such as portion size (Rolls, Morris, & Roe, 2002), palatability (de Graaf, de Jong, & Lambers, 1999; Drewnowski, 1998), and differences in sensory properties like moistness (Viskaal-van Dongen, Kok, & de Graaf, 2011). The various methods of ED reduction could also influence energy intake over the day by engaging different biological mechanisms. Changes in macronutrients, fiber, and moistness associated with reductions in ED could affect gastric emptying and release of satiety hormones and thereby influence both the magnitude and the time course of effects on intake (Burton-Freeman, 2000; Chaudhri, Small, & Bloom, 2006; Lejeune, Westerterp, Adam, Luscombe-Marsh, & Westerterp-Plantenga, 2006; Marciani et al., 2012). Engagement of these various biological mechanisms has led some researchers to propose that the different methods to reduce ED could lead to differences in the persistence of the effect on energy intake beyond a meal (Stubbs, Ferres, & Horgan, 2000; Westerterp-Plantenga, 2004). Because of the numerous processes involved, it is possible that energy consumption over the day will be differentially influenced by the method of ED reduction.

The present study therefore investigated whether energy intake at individual eating occasions and over the day differed when the entrées at main meals were reduced in ED by 20% using different methods. Since variations in palatability can mask other attributes of food that affect *ad libitum* consumption or satiation (de Graaf et al., 1999; Drewnowski, 1998), we sought to match palatability across conditions. Because a number of previous studies have shown that people tend to eat a consistent weight of food when palatability is matched and ED is reduced, we hypothesized that all three methods of reducing entrée ED would decrease energy intake at all meals and over the day compared to serving entrées of a higher ED. However, because these three methods can have different effects on sensory and physiological processes, we also tested the hypothesis that they would vary in their effects on energy intake at individual eating occasions and over the day.

METHODS

Subjects

Men and women aged 20 to 45 y were recruited for the study through advertisements in campus electronic newsletters and newspapers from September 2010 to March 2011. Telephone interviews were conducted with potential participants to determine whether they met the initial study criteria, including that they had a body mass index (BMI; kg/m^2) between 18-40, regularly ate three meals per day, did not have any food allergies or restrictions, were not dieting, were not athletes in training, were not taking medications that would affect appetite, did not smoke, and were willing to consume the foods served in the test meals. Potential subjects who met the initial study criteria came to the laboratory to rate the taste of food samples, including the standard versions of lunch and dinner entrées that were served in the study, and to have their height and weight measured (model 707; Seca Corp., Hanover, MD, USA). The following questionnaires were completed: a demographic and health questionnaire; the Eating Attitudes Test (Garner, Olmsted, Bohr, & Garfinkel, 1982), which assesses indicators of disordered eating; the Zung Self-Rating Scale (Zung, 1986), which evaluates symptoms of depression; and the Eating Inventory (Stunkard & Messick, 1985), which measures disinhibition, dietary restraint, and tendency toward hunger. Potential subjects were excluded if they had a taste rating for any entrée sample $\leq$ 30 mm on a 100-mm scale; a score $\geq$ 20 on the Eating Attitudes Test; or a score $\geq$ 40 on the Zung scale.

The sample size for the experiment was estimated using data from previous one-day studies in the laboratory. The minimum difference in daily energy intake assumed to be clinically significant was 200 kcal (837 kJ). A power analysis estimated that a sample size of 40 was needed to detect this difference in daily energy intake with > 80% power using a two-sided test with a significance level of 0.05.

Subjects were told the purpose of the study was to investigate eating behaviors at different meals. All subjects provided signed consent and were financially compensated $75 for their participation. The Pennsylvania State University Office for Research Protections approved all aspects of the study. A total of 32 men and 30 women were enrolled in the study. One man and one woman were excluded from the study for noncompliance with the study protocol. The data of one additional man was excluded for having undue influence on the outcomes according to the procedure of Littell, Milliken, Stroup, Wolfinger, and Schabenberger (2006); this individual had extremely low intakes on one test day. Thus, a total of 30 men and 29 women completed the study. The characteristics of these subjects are given in **Table 2-1**.

TABLE 2.1. Characteristics of subjects in a study in which the energy density of entrées was reduced by decreasing fat, increasing fruit and vegetables, or adding water[1]

Characteristic	Men (n = 30)		Women (n = 29)	
	Mean ± SEM	Range	Mean ± SEM	Range
Age (y)	26.1 ± 1.0	20.3-43.1	25.6 ± 1.1	20.3-44.9
Height (m)	1.79 ± 0.01	1.69-1.91	1.66 ± 0.01[a]	1.56-1.83
Weight (kg)	78.1 ± 1.7	62.7-100.0	61.5 ± 1.8[a]	48.4-90.0
Body mass index (kg/m^2)	24.5 ± 0.5	20.3-29.8	22.4 ± 0.7[a]	18.6-36.9
Dietary restraint score[3]	6.3 ± 0.7	0-14	8.7 ± 0.8[a]	0-15
Disinhibition score[3]	4.4 ± 0.4	0-9	5.2 ± 0.6[a]	1-15
Hunger score[3]	4.2 ± 0.6	0-12	3.9 ± 0.6	0-13

[1] All values are means ± SEMs
[2] Daily energy expenditure was estimated from sex, age, height, weight, and activity level (33).
[3] Scores from the Eating Inventory (31).
[a] Mean for women is significantly different from men ($P < 0.04$).

Study design

This experiment used a crossover design with repeated measures within subjects. The order of experimental conditions was counterbalanced across subjects using Latin squares and the orders were randomly assigned to subjects. Once a week for four weeks, participants were provided with all of their foods and beverages for breakfast, lunch, dinner, and evening snack. Across test days, the entrées served at the three meals were varied in ED between a standard level (100%) and a reduced level (80% of the standard). There were three reduced-ED versions of the entrées: decreased fat, increased fruit and vegetables (F&V), and added water.

Manipulated entrées

The composition of the entrées is shown in **Table 2-2**. The ED of the standard entrées was 1.8 kcal/g (7.54 kJ/g), which is similar to that of typical main dishes. The ED of the reduced entrées was 1.44 kcal/g (6.03 kJ/g). The use of separate methods to reduce ED limited the choice of entrées and imposed constraints on the degree to which ED could be reduced. The 20% reduction in ED allowed the use of single methods without changing the form of the food (i.e. adding an amount of water that would make a soup). Although the reduced entrées had the same ED, they differed in their proportion of macronutrients, fiber content, and moisture. On all test days, participants were served 700 g of the breakfast entrée and 900 g of both the lunch and dinner entrées (**Photograph 1**). These entrée amounts were chosen so subjects' food intake would not be limited by the amount of food provided.

The entrées were covertly manipulated in ED in order to minimize differences in appearance and taste across the conditions. The versions of the entrées for each meal had the same ingredients, but the proportions of the ingredients were varied based on the experimental condition. The entrées decreased in fat were prepared by removing butter or oil from the recipes. For the entrées increased in F&V, the amount of fruit was increased in the breakfast entrée and the amount of vegetables was increased in the lunch and dinner entrées. The F&V were either chopped in small pieces or puréed so that the increase in amount was less noticeable. The entrées with added water contained a greater amount of tap water. To create the reduced-ED entrées from the standard version, the weights of the manipulated ingredients and all other recipe ingredients were exchanged proportionally; this maintained the total amount of food served to avoid the introduction of confounding effects due to differences in portion size (Rolls et al., 2002). Water losses due to cooking were accounted for in the calculation of ED. A bomb calorimeter (model 1261; Parr Instrument Co, Moline, IL, USA) was used to verify that the planned reduction in ED of the entrées was achieved.

TABLE 2-2. Composition of the manipulated entrées served at breakfast, lunch, and dinner in a study in which the energy density was reduced by decreasing fat, increasing fruit and vegetables, or adding water

	100% energy density	80% energy density		
	Standard	Decreased fat	Increased fruit and vegetables	Added water
Breakfast (700 g)				
Oatmeal				
Energy (kcal)	1256	999	1002	1002
Energy (kJ)	5259	4183	4195	4195
Carbohydrate (% energy)	53.7	72.5	59.2	53.7
Protein (% energy)	11.5	15.6	10.4	11.5
Fat (% energy)	34.8	11.9	30.4	34.8
Fiber (g)	18.6	19.2	14.4	14.9
Energy density (kcal/g)	1.79	1.43	1.43	1.43
Energy density (kJ/g)	7.49	5.99	5.99	5.99
Fruit & vegetables (g)	17.0	18.2	226.6	13.6
Added water (g)	0.0	0.0	0.0	141.6
Lunch (900 g)				
Tex-Mex pasta casserole				
Energy (kcal)	1594	1276	1276	1277
Energy (kJ)	6674	5342	5342	5347
Carbohydrate (% energy)	45.7	59.7	47.2	45.7
Protein (% energy)	15.0	19.6	15.0	15.0
Fat (% energy)	39.3	20.7	37.8	39.3
Fiber (g)	15.1	15.8	14.6	12.2
Energy density (kcal/g)	1.77	1.42	1.42	1.42
Energy density (kJ/g)	7.41	5.95	5.95	5.95
Fruit & vegetables (g)	15.4	16.1	222.6	12.3
Added water (g)	0.0	0.0	0.0	183.0
Dinner (900 g)				
Chicken rice casserole				
Energy (kcal)	1586	1273	1273	1273

Energy (kJ)	6640	5330	5330	5330
Carbohydrate (% energy)	45.1	59.0	46.3	45.1
Protein (% energy)	14.9	19.5	15.4	14.9
Fat (% energy)	40.0	21.5	38.3	40.0
Fiber (g)	6.5	6.8	9.6	5.2
Energy density (kcal/g)	1.76	1.41	1.41	1.41
Energy density (kJ/g)	7.37	5.90	5.90	5.90
Fruit & vegetables (g)	58.2	60.9	268.2	46.8
Added water (g)	255.0	266.6	195.4	393.4

[1]Recipes available upon request to the corresponding author.

Photograph 1. Test meals served at breakfast (left), lunch (middle), and dinner (right).

Meals and evening snack

On each test day, participants were served breakfast, lunch, and dinner meals that included a manipulated entrée and unmanipulated side dishes; all foods served were consumed *ad libitum,* but subjects could not ask for additional servings. The entrée was the main source of energy at the meal and the side dishes were served to provide variety. Side dishes consisted of small amounts of food that differed in ED and were appropriate for the meal (**Table 2-3**). A variety of evening snacks that differed in ED were provided in order to determine whether the method used to reduce ED would result in differences in energy intake at the subsequent unmanipulated eating occasion.

One liter of water was served with each meal in addition to the choice of coffee or tea with breakfast. To allow measurement of water intake, bottled water was provided for consumption outside of the laboratory between meals and could be consumed as desired up to one hour before each meal. Bottled water was also provided with the evening snack. All foods and beverages were weighed before and after meals and the amount consumed was recorded to the nearest 0.1g. Energy and macronutrient intakes were calculated using information from a standard nutrient database (U.S. Department of Agriculture, Agricultural Research Service, 2008) and food manufacturers.

TABLE 2-3. Composition of foods served as side dishes at meals and for evening snack in a study that reduced the energy density of entrées by decreasing fat, increasing fruit and vegetables, or adding water

Meal	Food	Amount (g)
Breakfast	Strawberry yogurt[1]	114
	Creamer[2]	15
Lunch	Unsweetened applesauce[3]	113
	White roll[4]	43
	Butter[5]	5
Dinner	Red grapes	76
	Wheat roll[6]	43
	Butter[5]	5
Evening snack	Fig newton cookie[7]	62
	Cheese popcorn[8]	56
	Baby carrots	150

[1] Yoplait USA Inc, Minneapolis, MN, USA
[2] Morningstar Foods LLC, Dallas, TX, USA
[3] Knouse Foods Co-Op Inc, Peach Glen, PA, USA
[4] Flowers Bakeries Food Service, Tucker, GA, USA
[5] Land O'Lakes Inc, Arden Hills, MN, USA
[6] Bakery de France, Rockville, MD, USA
[7] Kraft Foods Global Inc, Northfield, IL, USA
[8] Frito-Lay Inc, Plano, TX, USA

Procedures

On the day prior to each test day, participants were instructed to keep their food intake and activity level consistent, to refrain from consuming alcohol, and to refrain from eating after 10 PM. They were asked to record this information to encourage compliance. On test days, they were instructed to consume only those foods and beverages provided by the researchers until midnight. Subjects came to the laboratory at scheduled meal times and were seated in individual cubicles. Lunch was served $\geq$ 3 h after breakfast, and dinner was served $\geq$ 4 h after lunch. Evening snack was consumed outside of the laboratory prior to midnight.

Before each meal, participants completed a brief questionnaire asking whether they had felt ill, taken any medications, or consumed any foods or beverages not provided by the researchers since the last meal. After completing the questionnaire, they were provided with their meal and were instructed to consume as much or as little as desired. Subjects were also given as much time as desired to eat their meals and the length of time taken to eat was recorded. Following the dinner meal, they were provided with bottled water and a variety of evening snacks for consumption at home. After the final meal of the study, subjects completed a discharge questionnaire to describe their ideas about the purpose of the study and any differences they noticed between test days. A validated fat preference questionnaire was also completed, which listed common foods available in different versions that varied in fat content; participants were asked to indicate which version of each food they thought tasted better and which version they ate most often. (Ledikwe et al., 2007)

Ratings of hunger, satiety, and food characteristics

Subjects used 100-mm visual analog scales (Flint, Raben, Blundell, & Astrup, 2000) to rate their hunger, fullness, prospective consumption, thirst, and nausea immediately before each test meal, after the meal, and immediately before consuming the evening snack. Participants also used visual analog scales to rate the overall liking, pleasantness of taste, calorie content, and fat content of the entrées at the beginning of the meal and immediately after the meal. Subjects were instructed to first serve themselves some of the entrée from the large serving bowl and then to take a bite of the entrée and answer the questions about the entrée characteristics. For example, participants were asked, “Based on what you are eating right now, how pleasant is the taste of this entrée?” The visual analog scale included anchors of “not at all pleasant” on the left and “extremely pleasant” on the right. In comparison, the anchors for the calorie content question were “very low in calories” on the left and “very high in calories” on the right. In addition, the moistness of the entrées was measured with a modified visual analogue scale that asked participants, “Based on what you are eating right now, how appropriate is the moistness of this entrée?” This modified scale had a “just right” indicator at the midpoint and included anchors of “much too dry” on the left and “much too moist” on the right. Immediately after the meal subjects were provided with a sample of the manipulated entrée and were instructed to eat the entire sample and then to answer all of the questions.

Data analysis

Data were analyzed using a mixed linear model with repeated measures (SAS System for Windows, version 9.3, SAS Institute, Inc., Cary, NC, USA). The fixed effects in the model were experimental condition (entrée version), subject sex, and study week. The primary outcomes for the study were energy intakes at each meal and for the entire day. To test the first hypothesis that all three methods of reducing entrée ED would decrease energy intake, the reduced-ED conditions were compared to the standard-ED condition and a Dunnett-Hsu adjustment was used to correct for multiple comparisons.

To test the second hypothesis that the methods of ED reduction had different effects on energy consumption over the day, three outcomes were investigated. Firstly, the magnitude of meal and daily energy intakes were compared across the reduced-ED conditions and a Tukey-Kramer adjustment was used to correct for multiple comparisons. As a second test of whether the methods of ED reduction differed in their effects, the curvature of cumulative energy intake over the day was examined across the reduced-ED conditions using a random coefficients analysis

(Brown & Prescott, 1999). It was expected that if the effects of one method were less persistent, the curve of cumulative energy intake would increase more steeply as the day progressed. In the random coefficients model, time was treated as a continuous covariate and lower-order polynomial factors of time were fitted if they were significantly related to the outcome. This model accounts for the correlation of the repeated measures within subjects by allowing the cumulative intake curve over the day to vary randomly for each participant. Finally, energy intake at the evening snack was compared across the reduced-ED conditions to determine whether any differences in satiety were indicated by differences at the unmanipulated eating occasion at the end of the day.

Secondary study outcomes were the weight of food consumed at meals and for the entire day; dietary ED over the day; macronutrient intakes at meals and over the day; participant ratings of hunger, satiety, and food characteristics; and eating rate. The calculation of dietary ED was determined using foods only; beverages were excluded (Ledikwe et al., 2005). Visual analog scales for hunger, satiety, and the food characteristics of overall liking, taste, calories, and fat ranged from 0 to 100. Ratings for moistness were assessed as the distance from the midpoint and ranged from -50 to 50. Summary measures of hunger and fullness for the day (including the ratings all time points at meals and evening snack) were calculated from the area under the curve of the ratings across time using the trapezoid formula (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). Analysis of covariance was used to determine whether any of the subject characteristics or participant ratings of entrée characteristics individually influenced the relation between the experimental condition and intakes of the manipulated entrées. Eating rate was calculated by dividing the weight of food consumed in grams by the time taken to eat the meal in minutes. Results are reported as mean ± standard error and were considered significant at $P < 0.05$.

RESULTS

Energy intake

Comparing standard- and reduced-ED conditions: Reducing the ED of entrées by each of the methods (decreasing fat, increasing F&V, or adding water) significantly decreased daily energy intake compared with the standard-ED entrées [$F(3,162) = 37.08$; $p < 0.0001$; **Figure 1-1A**]. The reduced-ED conditions decreased daily energy intake by a mean of 396 ± 44 kcal (1658 ± 184 kJ) when fat was decreased, by 308 ± 41 kcal (1290 ± 172 kJ) when F&V were increased, and by 230 ± 35 kcal (963 ± 147 kJ) when water was added. These differences were equivalent to a reduction over the day of 15, 11, and 9% of mean energy intake, respectively. For both men and women, energy intake from the entrées accounted for about two-thirds of daily energy intake. Energy intakes in all three reduced-ED conditions were significantly decreased at breakfast, lunch, and dinner compared to the standard-ED condition (**Table 2-5**).

Comparing the methods used to reduce ED: A comparison of the methods used to reduce ED showed that daily energy intake differed significantly [$F(2, 107) = 8.90$; $p < 0.001$; Figure 1-1A]. Daily energy intake was lowest when entrées were decreased in fat and was a mean of 89 ± 39 kcal (373 ± 163 kJ) higher when F&V were increased and 166 ± 37 kcal (695 ± 155 kJ) higher when water was added. When assessing individual meals, energy intake at breakfast and lunch, but not dinner, varied significantly according to the method of ED reduction (Table 2-5). Compared to when entrées were decreased in fat, energy intake was a mean of 46 ± 13 kcal (193 ± 54 kJ) higher at breakfast when F&V were increased [$F(2,113) = 6.82$; $p < 0.01$] and 66 ± 21 kcal (276 ± 88 kJ) higher at lunch when water was added [$F(2,107) = 5.66$; $p < 0.01$]. There were no significant differences in energy intake at meals when comparing the conditions in which F&V or water was increased. In contrast to the findings for daily and meal energy intakes, the curve for cumulative daily energy intake did not differ significantly across the methods used to reduce ED [F(2,595) = 2.44; p = 0.09; data not shown]. The pattern of energy consumption over the day was characterized by a similar second-order polynomial for all the reduced-ED conditions. Lastly, energy intake at the unmanipulated evening snack did not differ across the reduced-ED conditions (mean 368 ± 12 kcal [1541 ± 50 kJ]).

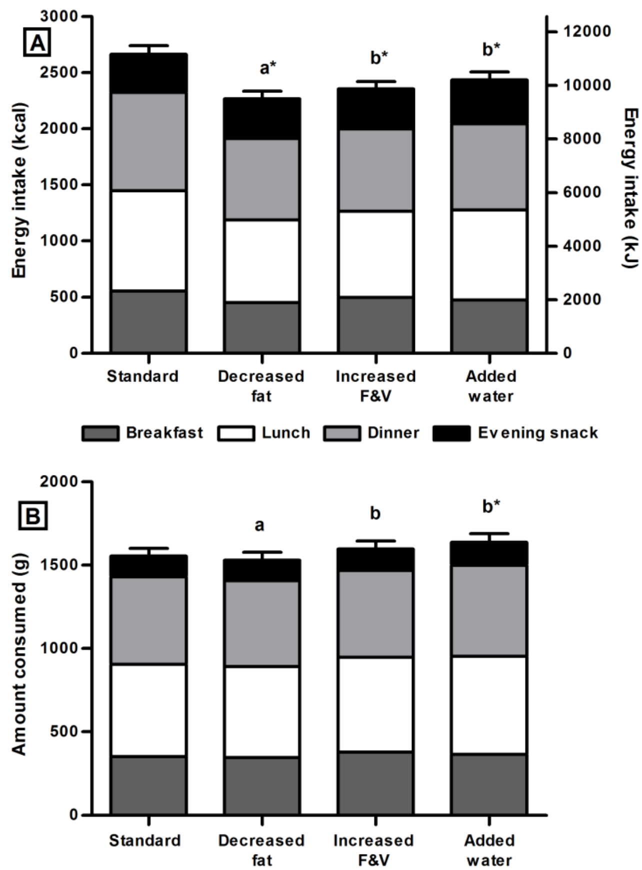

Figure 1-1. Mean (±SEM) energy (A) and food (B) intakes by condition at meals and evening snack consumed by 59 men and women who were served manipulated entrées at each meal that were either standard in energy density (ED) or reduced in ED by decreasing fat, increasing fruit and vegetables (F&V), or adding water. Means with different letters were significantly different across the reduced-ED conditions ($P < 0.02$) as assessed by a mixed linear model with repeated measures and with a Tukey-Kramer adjustment for multiple comparisons. Means marked with an asterisk were significantly different than the standard-ED condition ($P < 0.0001$) as assessed by a mixed linear model with repeated measures and with a Dunnett-Hsu adjustment.

Weight of foods and beverages consumed

Comparing standard- and reduced-ED conditions: Compared to the standard-ED condition, the total weight of food consumed over the day did not differ significantly when ED was reduced by decreasing fat or increasing F&V. Reducing ED by adding water, however, increased the daily weight of food consumed by 83 ± 23 g compared to the standard-ED condition [$F(3,170) = 8.06$; $p < 0.0001$; **Figure 1-1B**]. In contrast to these findings, the total weight of food consumed at individual meals (breakfast, lunch, and dinner) did not differ significantly between the conditions that were standard in ED or reduced in ED by adding water or decreasing fat. On the other hand, when F&V were increased, a significantly greater weight of food was consumed at breakfast but not at lunch or dinner compared to the standard-ED condition [$F(3,171) = 5.58$; $p < 0.01$; Table 2-5]. The weight of unmanipulated foods (side dishes and evening snack) consumed was not significantly different between the standard- and reduced-ED conditions.

Comparing the methods used to reduce ED: The method used to reduce ED had a significant impact on the weight of food consumed over the day [$F(2,111) = 10.37$; $p < 0.0001$; Figure 1B]. Participants consumed a mean of 109 ± 24 g more when water was added and 70 ± 23 g more when F&V were increased compared to when fat was decreased. When individual meals were examined, the method of ED reduction significantly influenced the weight of food consumed at breakfast and lunch but not dinner (Table 2-5). Compared to when fat was decreased, the weight of food consumed at breakfast was a mean of 32 ± 9 g more when F&V were increased [$F(2,113) = 6.51$; $p < 0.01$] and at lunch was 43 ± 15 g more when water was added [$F(2,108) = 4.81$; $p < 0.02$]. Across the methods, there were no significant differences in the weight of unmanipulated side dishes and evening snack consumed. The daily amount of water consumed as a beverage also did not differ significantly across the methods.

Macronutrient and fiber intakes

Daily intakes of fat, carbohydrate, protein, and fiber are shown in **Table 2-4**. Macronutrient and fiber intakes for the day varied significantly across the methods, as expected from the differences in entrée composition. For example, a reduction in ED by decreasing fat resulted in a daily intake of protein that was 15 ± 2 g more than increasing F&V and 12 ± 1 g more than adding water [$F(2,106) = 59.57$; $p < 0.0001$]. In addition, both decreasing fat and increasing F&V led to a small but significant increase in daily fiber intake of 2 ± 3 g compared to when water was added [$F(2,113) = 16.93$; $p < 0.0001$].

Macronutrient and fiber intakes at each meal also differed significantly across the methods (Table 2-5). For instance, protein intake at dinner was 5 ± 1 g higher when fat was decreased compared to the other two methods [$F(2,95) = 31.02$; $p < 0.0001$]. Fiber intake at dinner also differed significantly for all three methods in that fiber intakes were greatest when F&V were increased, intermediate when fat was decreased, and lowest when water was added [$F(2,113) = 135$; $p < 0.0001$]. However, fiber intakes differed by less than 2 g between any of the methods. At the evening snack there were no significant differences in intakes of fat, carbohydrate, protein, or fiber across the reduced-ED conditions.

TABLE 2-4. Daily intakes for 59 participants in a study in which the energy density of entrées was reduced by decreasing fat, increasing fruit and vegetables, or adding water[1]

	100% energy density	80% energy density		
	Standard	Decreased fat	Increased fruit and vegetables	Added water
Energy (kcal)	2668 ± 77	2272 ± 66[a#]	2360 ± 66[b#]	2438 ± 72[b#]
Energy (kJ)	11,170 ± 322	9512 ± 276[a#]	9881 ± 276[b#]	10,207 ± 301[b#]
Weight (g)	1554 ± 46	1529 ± 49[a]	1598 ± 48[b]	1637 ± 52[b#]
Carbohydrate (g)	358 ± 10	365 ± 11[a]	332 ± 9.0[b#]	328 ± 10[b#]
Protein (g)	85 ± 3	87 ± 3[a]	73 ± 2[b#]	76 ± 3[b#]
Fat (g)	105 ± 3	55 ± 2[a#]	88 ± 3[b#]	96 ± 3[c#]
Fiber (g)	26 ± 0.8	27 ± 0.8[a]	27 ± 0.8[a]	25 ± 0.7[b#]
Energy density (kcal/g)	1.72 ± 0.01	1.49 ± 0.01[a#]	1.48 ± 0.01[a#]	1.49 ± 0.01[a#]
Energy density (kJ/g)	7.20 ± 0.04	6.24 ± 0.04[a#]	6.24 ± 0.04[a#]	6.24 ± 0.04[a#]

[1]All values are means ± SEMs.
[a,b,c] Values in the same row with different superscript letters were significantly different ($P < 0.04$) as assessed by a mixed linear model with repeated measures and with a Tukey-Kramer adjustment for multiple comparisons.
[#]Values in the same row that are marked with a superscript # were significantly different from the standard ED condition ($P < 0.01$) as assessed by a mixed linear model with repeated measures and with a Dunnett-Hsu adjustment for multiple comparisons.

Energy density

Reducing the ED of entrées led to a significant decrease in ED over the day compared to the standard-ED entrées [$F(3,171) = 254.61$; $p < 0.0001$; Table 2-4]. Comparing the reduced-ED conditions, dietary ED over the day did not differ significantly by the method used to reduce ED. The overall ED of the foods consumed was 1.72 ± 0.01 kcal/g (7.20 ± 0.04 kJ/g) when ED was standard and 1.49 ± 0.01 kcal/g (6.24 ± 0.04 kJ/g) when ED was reduced. There was no difference in the ED of foods consumed at the evening snack across conditions. Thus, the 20% reduction in ED of the three entrées, which accounted for approximately two-thirds of daily energy intake, led to a 13% reduction in dietary ED over the day.

Table 2-5. Intakes by meal for 59 participants in a study in which the energy density of entrées was reduced by decreasing fat, increasing fruit and vegetables, or adding water[1,2]

	100% energy density	80% energy density		
	Standard	Decreased fat	Added fruit & vegetables	Added water
Breakfast				
Energy (kcal)	553 ± 25	451 ± 19[a#]	497 ± 21[b#]	475 ± 20[ab#]
Energy (kJ)	2315 ± 105	1888 ± 80	2080 ± 88	1989 ± 84
Weight (g)	350 ± 14	346 ± 14[a]	378 ± 15[b#]	364 ± 14[ab]
Fat (g)	20 ± 1.0	6 ± 0.3[a#]	16 ± 0.7[b#]	17 ± 0.8[b#]
Carbohydrate (g)	82 ± 4	85 ± 4[a]	80 ± 3[b]	71 ± 3[c#]
Protein (g)	17 ± 0.7	18 ± 0.8[a]	14 ± 0.6[b#]	15 ± 0.6[b#]
Fiber (g)	7 ± 0.3	7 ± 0.4[a]	6 ± 0.3[b#]	6 ± 0.3[b#]
Lunch				
Energy (kcal)	896 ± 33	736 ± 26[a#]	771 ± 29[ab#]	802 ± 28[b#]
Energy (kJ)	3751 ± 138	3081 ± 109	3228 ± 121	3358 ± 117
Weight (g)	556 ± 19	545 ± 19[a]	570 ± 21[ab]	588 ± 21[b]
Fat (g)	36 ± 1.5	17 ± 0.6[a#]	29 ± 1.3[b#]	32 ± 1.3[b#]
Carbohydrate (g)	116 ± 4	118 ± 4[a]	104 ± 7[b#]	105 ± 3[b#]
Protein (g)	32 ± 1	33 ± 1[a]	27 ± 1[b#]	29 ± 1[b#]
Fiber (g)	10 ± 0.3	10 ± 0.3[a]	10 ± 0.3[a]	9 ± 0.3[b#]
Dinner				
Energy (kcal)	878 ± 32	728 ± 29[a#]	735 ± 27[a#]	771 ± 33[a#]
Energy (kJ)	3676 ± 134	3048 ± 121	3077 ± 113	3228 ± 138
Weight (g)	525 ± 18	517 ± 21[a]	522 ± 19[a]	547 ± 23[a]
Fat (g)	35 ± 1.4	16 ± 0.7[a#]	27 ± 1.2[b#]	30 ± 1.4[b#]
Carbohydrate (g)	112 ± 4	114 ± 4[a]	98 ± 3[b#]	100 ± 4[b#]
Protein (g)	30 ± 1	31 ± 1[a]	26 ± 1[b#]	26 ± 1[b#]
Fiber (g)	5 ± 0.1	5 ± 0.2[a]	6 ± 0.2[b#]	4 ± 0.1[c#]
Evening snack				
Energy (kcal)	340 ± 25	357 ± 20[a]	358 ± 23[a]	389 ± 19[a#]
Energy (kJ)	1424 ± 105	1495 ± 84	1499 ± 96	1629 ± 80
Weight (g)	123 ± 11	121 ± 10[a]	128 ± 11[a]	138 ± 10[a]
Fat (g)	14 ± 1.2	16 ± 1.0[a]	15 ± 1.1[a]	17 ± 0.9[a#]
Carbohydrate (g)	48 ± 4	48 ± 3[a]	49 ± 3[a]	52 ± 3[a]
Protein (g)	5 ± 0.4	6 ± 0.3[a]	5 ± 0.4[a]	6 ± 0.3[a#]
Fiber (g)	5 ± 0.4	5 ± 0.4[a]	5 ± 0.4[a]	6 ± 0.4[a#]

[1]All values are means ± SEMs.

[2]Breakfast, lunch, and dinner meals include the entrée plus side dishes and the evening snack includes all foods that were provided.

[a,b,c] Values in the same row with different superscript letters were significantly different (P < 0.04) as assessed by a mixed linear model with repeated measures and with a Tukey-Kramer adjustment for multiple comparisons.

[#]Values in the same row that are marked with a superscript symbol (#) were significantly different from the standard ED condition ($P < 0.04$) as assessed by a mixed linear model with repeated measures and with a Dunnett-Hsu adjustment.

Ratings of hunger, satiety, and food characteristics

Participant ratings of hunger, fullness, thirst, prospective consumption, and nausea did not vary significantly based on ED or the method used to reduce ED either before or after meals or at the evening snack. Summary measures of hunger and fullness (area under the curve) also did not differ significantly across conditions (data not shown). Thus, ratings of hunger and fullness did not differ according to the method used to reduce ED.

Ratings of food characteristics for each of the entrées are shown in **Table 2-6**. All entrées were well liked by subjects as evidenced by mean ratings for pleasantness of taste from 60 to 80 mm. None of the reduced-ED entrées were rated significantly different in overall liking than the standard-ED versions. Participant ratings of entrée fat and calorie content did not differ significantly even though there were large differences in fat and calorie content across conditions. In contrast, moistness ratings differed significantly across conditions at each meal. The breakfast entrée with increased fruit as well as the lunch and dinner entrées with added water were rated significantly moister than the other versions of the same entrées. Analysis of covariance showed that the differences in entrée characteristic ratings did not influence the effect of the method of ED reduction on intake of the manipulated entrées.

Eating rate (g/min) also varied significantly across the methods at breakfast and lunch. At breakfast, eating rate was faster when fruit was increased (43.0 ± 2.2 g/min) than when either fat was decreased (38.2 ± 2.0 g/min) or water was added (37.6 ± 2.0 g/min) [$F(2,109) = 6.68$; $p < 0.01$]. At lunch, eating rate was faster when water was added (48.2 ± 1.7 g/min) than when either fat was decreased (43.4 ± 1.7 g/min) or vegetables were increased (45.6 ± 1.7 g/min) [$F(2,111) = 10.51$; $p < 0.0001$].

TABLE 2-6. Ratings of food characteristics for each of the manipulated entrées for 59 participants in a study in which the energy density of entrées was reduced by decreasing fat, increasing fruit and vegetables, or adding water[1]

	100% energy density	80% energy density		
	Standard	Decreased fat	Increased fruit and vegetables	Added water
Oatmeal				
Overall liking	70 ± 2	64 ± 2[a]	70 ± 2[b]	67 ± 2[ab]
Taste	70 ± 2	66 ± 2[a]	71 ± 2[a]	67 ± 2[a]
Fat	30 ± 2	28 ± 2[a]	29 ± 2[a]	29 ± 2[a]
Calories	44 ± 3	42 ± 3[a]	43 ± 2[a]	43 ± 3[a]
Moistness	-1 ± 2	-4 ± 2[a]	8 ± 2[b#]	-1 ± 2[a]
Tex-Mex pasta casserole				
Overall liking	78 ± 2	77 ± 2	78 ± 2[a]	74 ± 2[a]
Taste	78 ± 2	78 ± 2[a]	78 ± 2[a]	75 ± 2[a]
Fat	54 ± 3	54 ± 3[a]	53 ± 3[a]	52 ± 3[a]
Calories	64 ± 2	61 ± 2[a]	61 ± 2[a]	60 ± 2[a]
Moistness	1 ± 1	-1 ± 1[a]	1 ± 1[a]	5 ± 1[b#]
Chicken rice casserole				
Overall liking	67 ± 2	68 ± 2[a]	63 ± 2[a]	66 ± 2[a]
Taste	67 ± 2	67 ± 3[a]	61 ± 3[b#]	62 ± 3[b#]
Fat	54 ± 3	49 ± 3[a]	52 ± 3[a]	52 ± 3[a]
Calories	61 ± 3	58 ± 2[a]	58 ± 3[a]	59 ± 3[a]
Moistness	4 ± 1	-1 ± 2[a#]	5 ± 2[b]	11 ± 2[c#]

[1]All values are means ± SEMs. Ratings for overall liking, taste, fat, and calories are from 100-mm visual analog scales. Ratings for moistness are from 100-mm visual analog scales but were assessed as the distance from the midpoint (50 mm) and are expressed as values ± 50 mm. A rating of zero represents “just right”, negative ratings are toward the “too dry” anchor, and positive ratings are toward the “too moist” anchor.

[a,b,c] Values in the same row with different superscript letters were significantly different ($P < 0.04$) as assessed by a mixed linear model with repeated measures and with a Tukey-Kramer adjustment for multiple comparisons.

[#]Values in the same row that are marked with a superscript symbol (#) were significantly different from the standard ED condition ($P < 0.02$) as assessed by a mixed linear model with repeated measures and with a Dunnett-Hsu adjustment.

Subject characteristics

Analysis of covariance showed that the relationships between experimental condition and the outcomes of daily energy and food intakes were not significantly influenced by participant age, weight, height, BMI, scores for disinhibition, dietary restraint, or tendency toward hunger, or scores on the fat preference questionnaire. Subjects who indicated a preference for high-fat foods did not differ in their energy intake or ratings of entrée fat content compared to subjects who did not prefer high-fat foods (data not shown). Additionally, the effect of condition on daily energy intake did not differ significantly between men and women [$F(2,108) = 2.07$; $P = 0.13$]. Comments from the discharge questionnaire showed that no participants accurately discerned the purpose of the study.

DISCUSSION

This study demonstrated that three different methods of reducing entrée energy density (decreasing fat, increasing fruit and vegetables, and adding water) all resulted in a substantial decrease in energy intake over one day. While all three methods were effective, decreasing fat led to the greatest reduction in energy intake for the entire day, although not at individual meals. Daily summary ratings of hunger and fullness were similar despite the differences in energy intake across the conditions. The curves for cumulative energy consumption over the day were also similar across the methods. These findings confirm the efficacy of reducing ED by a variety of methods in order to moderate energy intake, but indicate that the magnitude of the effect may depend upon factors such as the method of ED reduction and the foods or meals being compared.

A possible explanation for the differences in food and energy intakes across the reduced-ED conditions is variations in the palatability and sensory characteristics of the entrées. Changes in these properties could influence the tendency for people to eat a similar amount of food when ED varies (Bell et al., 1998; Blatt et al., 2011; Stubbs et al., 1998) and therefore might explain why food intakes were lower when entrées were reduced in fat. Although we sought to limit the influence of palatability (de Graaf et al., 1999; Drewnowski, 1998), the use of single methods of ED reduction made it difficult to eliminate all of the differences in sensory characteristics. We found that ratings of the pleasantness of the taste of the entrées were similar at breakfast and lunch but differed at dinner. Palatability ratings at dinner did not relate to meal intake, however, suggesting that other factors contributed to intake differences. The use of single methods of ED reduction also influenced the moistness of entrées, which could affect ease of consumption, eating rate, and food and energy intakes (Andrade, Greene, & Melanson, 2008; Viskaal-van Dongen et al., 2011). We found that an increase in either water or F&V generally resulted in entrées that were rated moister and were associated with faster eating rates compared to the reduced-fat entrées. Although energy intakes tended to be higher for the entrées that were rated moister, these ratings were not significantly related to intake in our study; it is possible that there may have been insufficient statistical power to detect such effects. Whether or not participants perceived differences in fat content could be another factor that influenced intake; yet, entrée fat content was rated similarly across the methods, suggesting that intake was not a result of participants noticing differences (Drewnowski, 1998). Although we did not find associations between intakes and the palatability or sensory characteristics of the reduced-ED entrées, it is still possible that variations in these properties influenced the tendency to consume similar amounts of food and thus affected energy intakes.

Another reason for the differences in energy intake across the methods could relate to variations in macronutrient composition of the entrées. We found that consumption of the reduced-fat entrées resulted in lower intakes of fat and higher intakes of protein compared to the other two methods. Previous research showed that changes in fat content did not significantly affect intake when ED was held constant (Rolls et al, 1999b; Raben, Agerholm-Larsen, Flint, Holst, & Astrup, 2003). When protein was increased and ED was held constant, however, energy intake was decreased in some studies (Gosby et al, 2011; Martens, Lemmens, & Westerterp-Plantenga, 2013) but not others (Blatt, Roe, & Rolls, 2011b; Raben et al., 2003). It remains possible that the decrease in daily energy intake from the consumption of reduced-fat entrées resulted from the small increases in protein intake at meals. Differences in macronutrient composition could affect intake through various mechanisms such as alterations in gastric emptying rates and post-ingestive hormones (Burton-Freeman, 2000; Chaudhri et al., 2006; Lejuene et al., 2006). Changes in these biological processes could affect not only the magnitude, but also the persistence of the effects on energy intake (Stubbs et al., 2000; Westerterp-Plantenga, 2004). In our study, however, we did not find differences in intake at the unmanipulated evening snack, the curvature of cumulative energy consumption, or ratings of hunger and fullness over the day. These findings suggest that the influence of ED on energy intake is not solely dependent on variations in the proportions of macronutrients. Additional research over longer periods will help to determine how biological processes and other factors associated with ED reduction combine and persist to influence energy intake.

Evaluating the results of adding either plain water or F&V to entrées made it possible to investigate whether F&V affected energy intake as a result of their fiber content. In comparison to the water condition, the addition of F&V led to a small (2 gram/d) increase in fiber intake, which was associated with no significant difference in daily energy intake. Previous investigations have shown that differences in fiber intakes as low as 14 grams over the day influence energy intake (Howarth, Saltzman, & Roberts, 2001), suggesting that the variations in fiber intake in this study were too small to exert different effects on energy intake over the day. Increasing the proportion of F&V in foods has the potential to decrease energy intake to a greater extent than adding water, because of the various effects that fiber can have on satiety (Burton-Freeman, 2000). Fruits and vegetables can also add bulk to foods and can increase the amount of chewing required (Burton-Freeman, 2000; Moorhead et al., 2006); however, these differences were lessened in our study since some of the F&V in the entrées were canned or puréed. The similarity in energy intake between the F&V and water conditions indicates that the effects on intake when F&V were increased were not attributable to their fiber content.

The impact that reductions in dietary ED can have on energy intake in studies of satiation depends upon the foods available to participants. For instance, in studies where all of the foods provided were reduced in ED, the decrease in energy intake paralleled the reduction in ED (Lissner et al., 1987; Rolls, Roe, & Meengs, 2006). In such situations, energy intake could be constrained, since the only way people can compensate for consuming less energy is to eat more of the manipulated foods (Westerterp-Plantenga, 2004). However, a number of studies have found that reductions in ED were associated with decreased energy intake when only a portion of the diet was manipulated (Blatt et al., 2011a; Rolls et al., 1999b). In this study, participants consumed similar amounts of unmanipulated side dishes and evening snack when given these opportunities to adjust for energy deficits associated with the reduction in ED of the entrées. The 20% reduction in ED was associated with a 9 to 15% decrease in daily energy intake, depending on the method, and these reductions are comparable to previous research in which only part of the diet was reduced in ED (Blatt et al., 2011a; Rolls et al., 1999b). It is possible that in an abundant environment where there are almost unlimited opportunities to eat, greater compensation for ED reductions than was found in our study would be seen. Nevertheless, this study showed that reducing ED by a variety of methods had robust effects on energy intake even when individuals were given the opportunity to compensate by eating other foods.

In conclusion, reducing the ED of entrées by decreasing fat, increasing fruit and vegetables, or adding water decreased daily energy intake compared to serving standard-ED entrées. Although in this study the reduced-fat entrées led to the lowest daily intake, it is important to recognize that the entrées were chosen in order to manipulate the composition in distinct ways while minimizing differences in sensory properties. In practice, not all foods are suitable for reduction in ED by each method. Because of the different effects on sensory properties associated with the different methods, individuals may prefer one over another; for example, people who like moister foods might choose to add water to reduce ED. Individuals may also favor one method for reasons related to health, such as incorporating F&V to help consume recommended amounts of these foods. The finding that all three methods reduced energy intake at meals and over the day suggests that individuals can modify the ED of foods using their preferred methods or a combination of methods, such as replacing oil with applesauce when baking (fat reduction along with increased fruit). The practical implication is that a variety of diet compositions can be recommended to reduce overall dietary ED in order to moderate energy intake.

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CHAPTER 3

Study 2:

Effects of energy content and energy density of pre-portioned entrées on energy intake

Blatt AD, **Williams RA**, Roe LS, Rolls BJ. Effects of energy content and energy density of pre-portioned entrées on energy intake. *Obesity* 2012;20:2010-8.

INTRODUCTION

Effective strategies are needed to help individuals manage their food intake in an environment filled with large portions of energy-dense foods. One strategy shown to be useful in moderating energy intake and managing body weight is the consumption of pre-portioned foods, such as liquid meal replacements and solid pre-portioned entrées (1-9). Although most research has investigated liquid meal replacements, several studies examined the consumption of solid pre-portioned entrées over multiple weeks and showed that participants achieved greater weight loss using the entrées than with self-selected diets (6-9). These studies, however, provided little data on how the characteristics of pre-portioned entrées influence satiety and energy intake. For example, if pre-portioned entrées are too restricted in energy content, they may not provide a satisfying portion of food; as a result, individuals may remain hungry and more likely to consume excessive energy from the wide assortment of foods that are readily available. The present study investigated how changes in the energy content and energy density (ED) of pre-portioned entrées influence satiety and energy intake over a day.

One approach for investigating the effects of pre-portioned entrées is to provide manipulated compulsory entrées followed by a variety of discretionary foods that allow compensation for differences in satiety (10). Most research using this type of preloading paradigm has tested foods that are typically eaten as a first course. Several studies have found that the energy content of a preload such as yogurt or soup influences satiety and energy intake at the following test meal (11-13). Other research has shown that satiety is also affected by the ED of preloads of soup or salad (14-16). For example, consumption of a large, low-ED salad reduced test meal energy intake compared to an equicaloric salad higher in ED and smaller in portion size (16). A few preloading studies have tested foods that are typically consumed as the main dish of a meal. In one study, manipulated entrées were served at three meals per day and additional discretionary foods were offered; it was found that daily energy intake was influenced by varying the ED, but not the fat content, of the equicaloric entrées (17). More information is needed about how entrées can be modified strategically to reduce energy intake at meals.

The objective of the present study was to use pre-portioned entrées in a preloading design to examine the effects of two food characteristics known to affect satiety: energy content and ED. We hypothesized that reductions in the energy content and ED of the entrées would act independently and add together to reduce daily energy intake. Changing the energy content and ED of foods leads to differences in portion size because these three food characteristics are directly related. In order to control the effects of portion size, in two of the experimental conditions entrée portions were matched while both energy content and ED were manipulated. We predicted that simultaneously reducing the energy content and ED of entrées with the same portion size would decrease energy intake over the day.

METHODS AND PROCEDURES

Study design

This experiment used a crossover design with repeated measures within subjects. One day a week for four weeks, participants were provided with all of their foods and beverages for breakfast, lunch, and dinner meals. Across test days, the entrée at each meal was varied in both energy content and ED between a standard level (100%) and a reduced level (64% of the standard). Following consumption of the compulsory entrée, a variety of unmanipulated discretionary foods was served for *ad libitum* consumption. For both the compulsory entrées and discretionary foods, women were served 70% of the amounts served to men. The order of experimental conditions was counterbalanced across the subjects.

Subjects

Men and women aged 20 to 45 years were recruited for the study through advertisements in newspapers, flyers, and campus electronic newsletters. Potential subjects were interviewed by telephone to determine whether they met the initial study criteria, including that they regularly ate three meals per day, did not smoke, did not have any food allergies or restrictions, were not athletes in training, were not dieting, were not taking medications that would affect appetite, and were willing to consume the foods served in the test meals.

Potential subjects who met the initial study criteria came to the laboratory to have their height and weight measured (model 707; Seca Corp., Hanover, MD, USA) and to rate the taste of food samples, including the entrées that were served in the study. The following questionnaires were completed: a demographic and health questionnaire; the Zung Self-Rating Scale (18), which evaluates symptoms of depression; the Eating Attitudes Test (19), which assesses indicators of disordered eating; and the Eating Inventory (20), which measures dietary restraint, disinhibition, and tendency toward hunger. Exclusion criteria included a taste rating for any entrée sample $\leq$ 30 mm on a 100-mm scale; a score $\geq$ 40 on the Zung scale; or a score $\geq$ 20 on the Eating Attitudes Test. Subjects were also excluded if they reported known health problems or had not maintained their weight within 4.5 kg (10 lb) during the 6 months before the start of the study.

The sample size for the experiment was estimated using data from previous one-day studies in the laboratory. The minimum difference in daily energy intake assumed to be clinically significant was 300 kcal for men and 200 kcal for women. A power analysis estimated that a sample size of 19 men and 26 women was needed to detect this difference in daily energy intake with >80% power using a two-sided test with a significance level of 0.05.

Subjects were told the purpose of the study was to monitor eating behaviors at different meals. Subjects provided signed consent and were financially compensated for their participation. A total of 31 men and 42 women were enrolled in the study. Three men and one woman were excluded from the study for noncompliance with the study protocol. The data of one additional woman was excluded for having undue influence on the outcomes according to the procedure of Littell, et al (21). Thus, a total of 28 men and 40 women completed the study (**Table 3-1**). All aspects of the study were approved by The Pennsylvania State University Office for Research Protections.

Table 3-1. Characteristics of study participants

Characteristic	Men (*n* = 28)		Women (*n* = 40)	
	Mean ± SEM	Range	Mean ± SEM	Range
Age (y)	26.8 ± 1.1	20-41	27.6 ± 1.1	20-43
Height (m)	1.77 ± 0.01	1.7-1.9	1.65 ± 0.01[a]	1.5-1.8
Weight (kg)	77.9 ± 2.0	62-107	63.5 ± 1.5[a]	49-91
BMI (kg/m^2)	24.9 ± 0.6	20-33	23.3 ± 0.6[a]	19-38
Energy requirement (kcal/d)[1]	2831 ± 38	2464-3164	2196 ± 24[a]	1847-2546
Dietary restraint score[2]	6.3 ± 0.6	1-13	8.3 ± 0.7[a]	1-16
Disinhibition score[2]	4.2 ± 0.4	0-9	4.5 ± 0.4	1-11
Hunger score[2]	4.7 ± 0.6	0-12	4.4 ± 0.5	0-13

[1] Estimated from sex, age, height, weight, and activity level (22).
[2] Scores from the Eating Inventory (20).
[a] Mean for women is significantly different from mean for men ($P < 0.0001$).

Foods and Meals

On each test day, participants were served breakfast, lunch, and dinner meals that included a compulsory manipulated entrée and a variety of unmanipulated discretionary foods that were consumed *ad libitum*. Across experimental conditions, the compulsory entrées were varied in both energy content and ED between a standard level and a reduced level. In addition, the reductions in energy content and ED were chosen so that each standard entrée was matched in portion size (weight) to the entrée of reduced energy content and reduced ED (**Table 3-2**). The entrées were selected because they could be covertly manipulated in ED and matched for palatability; the discretionary foods served at the test meal were commonly consumed items that were not varied in energy content or ED (**Table 3-3**).

Table 3-2. Total energy content, weight, and energy density of compulsory entrées served in the experimental conditions

	Energy content condition			
	Men (n = 28)		Women (n = 40)	
Energy density condition	**Standard**	**Reduced**	**Standard**	**Reduced**
Standard				
Entrée energy (kcal/d)	1570	1000	1100	700
Entrée weight (g/d)	**980**	615	**690**	430
Entrée energy density (kcal/g)	1.6	1.6	1.6	1.6
Reduced				
Entrée energy (kcal/d)	1570	1000	1100	700
Entrée weight (g/d)	1570	**980**	1100	**690**
Entrée energy density (kcal/g)	1.0	1.0	1.0	1.0

Numbers are rounded to the nearest 10 kcal and 10 grams. Bolded numbers represent the entrées matched in weight (portion size).

Table 3-3. Unmanipulated discretionary foods served at each meal

	Men (n = 28)		Women (n = 40)	
	Energy (kcal)	**Weight (g)**	**Energy (kcal)**	**Weight (g)**
Breakfast				
Mandarin oranges[1]	202	349	141	244
Plain bagels[2]	353	143	247	100
Condiments (cream cheese[3], butter[4], jelly[5])	622	220	622	220
Lunch				
Buttered broccoli[4,6]	200	243	140	170
Rice pilaf[7]	314	221	220	155
Grapes	224	324	157	227
Chocolate chip cookies[8]	416	86	290	60
Dinner				
Salad with sliced tomatoes	22	127	17	98
Assorted dressings[9]	760	258	760	258
Croutons[10]	86	20	60	14
Crackers[8]	345	71	243	50
Cubed cheese[8]	344	86	240	60
Peaches[1]	130	323	91	226
Pound cake[2]	316	80	221	56

[1] Independent Marketing Alliance, Houston, TX, USA
[2] Sara Lee Corporation, Downers Grove, IL, USA
[3] Kraft Foods North America, Inc., Glenview, IL, USA
[4] Land O'Lakes Inc, Arden Hills, MN, USA
[5] J.M. Smucker Company, Orrville, OH, USA
[6] Birds Eye Foods, Inc., Rochester, NY, USA
[7] MARS Food US, LLC, Carson, CA, USA
[8] Kraft Foods Global, Inc., Northfield, IL, USA
[9] T. Marzetti Company, Columbus, OH, USA
[10] Pepperidge Farm, Inc., Norwalk, CT, USA

The standard-energy versions of the compulsory entrées were designed to provide approximately 50-60% of daily energy intake, based on nationally representative data (23); thus, women received 70% of the amount that was provided to men. The reduced-energy entrées provided ~64% of the energy in the standard entrées; the reduction was accomplished by providing a smaller portion of food. Across the entire test day, the difference in compulsory energy intake from the standard-energy and reduced-energy entrées was 567 kcal for men and 403 kcal for women. Total energy content from the compulsory entrées was distributed to provide approximately 27% of the compulsory energy at breakfast, and 36.5% of the compulsory energy at both lunch and dinner. For the discretionary foods, which were not varied in energy content and were consumed *ad libitum*, the amounts served to women were 70% of those served to men. The foods provided to men and women can be found in **Photograph 2**.

The ED of the standard entrées was 1.6 kcal/g, similar to that of commercially available portion-controlled entrées intended for non-dieters. The ED of the reduced entrées was 1.0 kcal/g, or ~64% of the standard ED; the reduction was accomplished by increasing the amount of vegetables or fruit. This ED is similar to that of commercially available portion-controlled entrées marketed for weight management. The ingredients in the entrées were adjusted to maintain approximately 15% of energy as protein, 30% of energy as fat, and 55% of energy as carbohydrate (**Table 3-4**). Thus, the reduction in ED was accomplished by increasing the water content of the entrées while maintaining the macronutrient content.

One liter of water was served with the discretionary foods at each meal in addition to the choice of coffee or tea with breakfast. To allow measurement of water intake, bottled water was provided for consumption outside of the laboratory between meals and could be consumed as desired up to one hour before each meal. All foods and beverages were weighed before and after meals and the amount consumed was recorded to the nearest 0.1 g. Energy and macronutrient intakes were calculated using information from food manufacturers and a standard nutrient database (24).

Photograph 2. Test meals served at breakfast (top), lunch (middle), and dinner (bottom) for men (left column) and women (right column).

Table 3-4. Composition of the manipulated entrées served at each meal

	Men (n = 28)				Women (n = 40)			
	Standard energy content		Reduced energy content		Standard energy content		Reduced energy content	
	Standard ED	Reduced ED	Standard ED	Reduced ED	Standard ED	Reduced ED	Standard ED	Reduced ED
Breakfast: Yogurt parfait								
Weight (g)	272	426	173	272	190	299	120	190
Energy (kcal)	430	430	275	275	300	300	190	190
Fat (g)	14.4	14.3	9.1	9.0	10.0	10.0	6.3	6.2
Carbohydrate (g)	63.2	64.2	40.2	41.1	43.9	44.8	27.7	28.0
Protein (g)	16.2	16.6	10.2	10.3	11.3	11.6	7.1	7.2
Fiber (g)	4.0	5.4	2.5	3.5	2.7	3.8	1.7	2.4
Lunch: Chicken rice casserole								
Weight (g)	356	566	229	356	250	395	160	250
Energy (kcal)	570	570	368	368	400	400	256	256
Fat (g)	18.9	18.9	12.4	12.5	13.2	13.3	8.6	8.7
Carbohydrate (g)	79.7	81.6	52.4	54.0	55.6	57.3	36.3	34.0
Protein (g)	21.7	22.0	14.1	14.6	15.1	15.3	9.8	10.1
Fiber (g)	2.9	7.6	1.8	5.0	2.1	7.1	1.4	4.7
Dinner: Pasta bake								
Weight (g)	356	570	223	356	250	400	157	250
Energy (kcal)	570	570	360	360	400	400	251	251
Fat (g)	19.2	19.1	12.0	12.1	13.5	13.1	8.5	8.3
Carbohydrate (g)	76.8	78.1	48.5	49.6	53.9	55.5	34.0	34.9
Protein (g)	22.0	21.9	14.0	13.7	15.3	15.2	9.6	9.6
Fiber (g)	8.0	11.9	5.1	7.6	5.6	8.4	3.5	5.2

ED: energy density

Procedures

Subjects were instructed to keep their food intake and activity level consistent on the day before each test day, and keep a record of this information to encourage compliance. They were also instructed to refrain from consuming alcohol within 24 hours of the test day and to refrain from eating after 10 pm the evening before each test day. During test days, subjects were instructed to consume only those foods and beverages provided by the researchers until after the dinner meal. On test days, subjects came to the laboratory at scheduled meal times and were seated in individual cubicles. Lunch was served at least 3 hours after breakfast, and dinner was served at least 4 hours after lunch.

Before each meal, participants completed a brief questionnaire asking whether they had felt ill, taken any medications, or consumed any foods or beverages not provided by the researchers since the last meal. After completing the questionnaire, participants were provided with the entrée portion of the meal and instructed to consume all of the entrée within 15 minutes. Two minutes later, the discretionary foods were served and subjects were instructed to consume as much or as little as desired. After the final meal of the study, subjects completed a discharge questionnaire to report their ideas about the purpose of the study and any differences they noticed between sessions.

Ratings of hunger, satiety, and food characteristics

Subjects used visual analog scales (25) to rate their hunger, fullness, thirst, and nausea immediately before each test meal, before receiving the discretionary foods, and after the meal. The characteristics of the entrées were also assessed using visual analog scales. Subjects were instructed to first rate the appearance of the entrée and then take a bite and answer the remaining questions about pleasantness of taste, pleasantness of texture, and calorie content.

Data analysis

Data were analyzed using a mixed linear model with repeated measures (SAS System for Windows, version 9.1, SAS Institute, Inc., Cary, NC, USA). The fixed effects in the model were entrée energy content and ED. Planned comparisons were also performed between the two conditions in which the entrées were matched for portion size. Because men and women were provided with different amounts of food, their data were analyzed separately. The primary outcomes for the study were discretionary food and energy intakes over the day (all three meals combined) and total food and energy intakes over the day (entrées plus discretionary foods). Secondary outcomes were food and energy intakes at each meal, dietary ED at each meal and over the day, and participant ratings of hunger, satiety, and food characteristics. The calculation of dietary ED was determined using foods only; beverages were not included (26). Summary measures of hunger and fullness for the day were calculated from the area under the curve of the ratings across time using the trapezoid formula (27). Subject characteristics were investigated as covariates in the main statistical model. Daily energy expenditure of participants was estimated from sex, age, height, weight, and activity level (22). Results are reported as mean ± standard error and were considered significant at $P < 0.05$.

RESULTS

Energy intake

Effects of entrée energy content

In men, reductions in entrée energy content had a significant effect on energy intake for the entire day, independent of reductions in ED (**Figure 2-1**). Decreasing the energy content of the compulsory entrées resulted in a significant decrease in daily energy intake of 311 ± 37 kcal or 12% ($P < 0.002$; **Table 3-5**). Energy intake from discretionary foods increased by 256 ± 37 kcal after men consumed the reduced-energy entrées rather than the standard-energy entrées ($P < 0.003$). This increase in discretionary energy intake, however, was insufficient to fully compensate for the 567 kcal reduction in energy content from the entrées. Analysis of each meal showed that in men, the effect of energy content on discretionary and total energy intake was significant at breakfast, lunch, and dinner ($P < 0.05$).

In women, reducing the energy content of entrées resulted in significant increases in discretionary energy intake and reductions in daily energy intake, but the magnitude of these changes depended on the level of entrée ED ($P < 0.03$; **Figure 2-2**). Decreasing the energy content of the standard-ED entrées reduced mean daily intake by 239 ± 30 kcal or 12%, and decreasing the energy content of the reduced-ED entrées reduced daily intake by 127 ± 39 kcal or 7% (Table 3-5). Analysis of each meal showed that in women, the effect of energy content on discretionary and total energy intake was independent of ED at breakfast and lunch ($P < 0.001$). At dinner, however, the effects of entrée energy content and ED interacted to affect discretionary and total energy intake ($P < 0.003$).

The standard entrées provided a mean of 56 ± 1% of the estimated daily energy requirements for men and 50 ± 1% of the daily requirements for women; these proportions were similar to the intended range of 50 to 60% in the study design. When discretionary energy intake was included, men met 100 ± 3% of their daily energy requirements in the standard condition and women met 95 ± 3% of their requirements.

Effects of entrée energy density

In men, decreases in entrée ED resulted in a significant effect on daily energy intake, independent of decreases in entrée energy content (Figure 2-1). Reducing the ED of entrées led to a significant reduction in energy intake from discretionary foods ($P < 0.005$) and over the day ($P < 0.01$) of 150 ± 26 kcal, or 5% (Table 3-5). Analysis of each meal showed that in men, the effect of entrée ED on discretionary and total energy intake was significant at lunch and dinner ($P < 0.03$). In women, decreasing the ED of the entrées led to different effects depending on the energy content of the entrées (Figure 2-2). In the entrées with standard energy content, decreasing the ED had significant effects on discretionary and daily energy intake ($P < 0.002$); the reduction in daily intake was 162 kcal ± 34 or 8% (Table 3-5). In the entrées with reduced energy content, however, decreasing the ED had no significant effect on discretionary or daily energy intake ($P = 0.59$); the 50 ± 33 kcal difference in daily intake was not statistically significant.

Combined effects of entrée energy content and energy density

Comparing the entrées of equal portion size allowed evaluation of the combined effects of energy content and ED (Figures 2-1 and 2-2). In both men and women, this comparison showed that simultaneously decreasing entrée energy content and ED resulted in a significant reduction in daily energy intake. In men, the reduction in daily energy intake was 445 ± 47 kcal, or about 16% ($P < 0.0001$), and in women, the reduction was 289 ± 35 kcal, or about 14% ($P < 0.0001$).

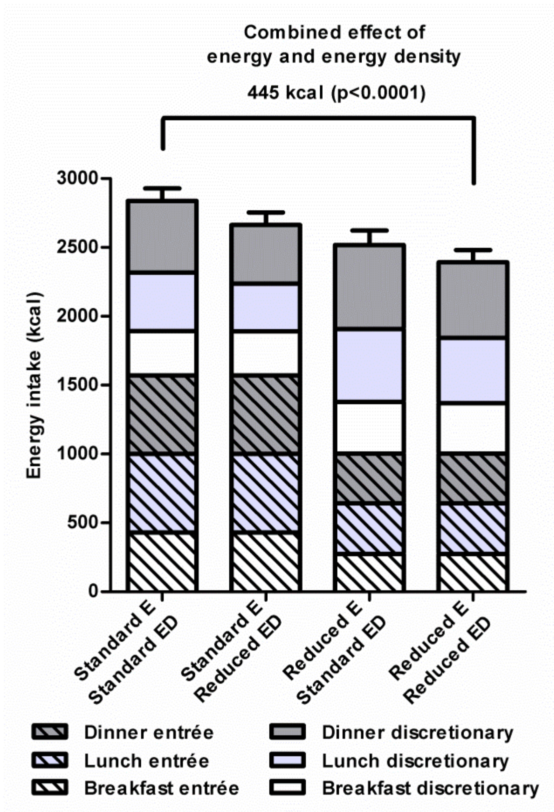

Figure 2-1. Mean (± SEM) energy intake for 28 men who were served compulsory entrées that were varied in energy content (E) and energy density (ED), followed by a variety of discretionary foods. The effects of the experimental factors on daily energy intake were independent and significant (both $P < 0.003$). Reducing both the energy content and ED of the entrées resulted in a 445 kcal decrease in daily energy intake ($P < 0.0001$).

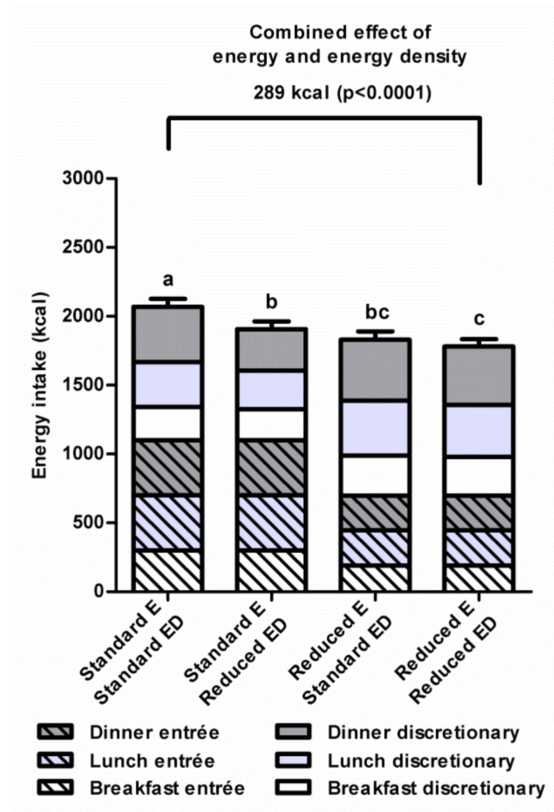

Figure 2-2. Mean (± SEM) energy intake for 40 women who were served compulsory entrées that were varied in energy content (E) and energy density (ED), followed by a variety of discretionary foods. The experimental factors interacted to affect daily energy intake; different letters represent means that are significantly different ($P < 0.03$). Reducing both the energy content and ED of the entrées resulted in a 289 kcal decrease in daily energy intake ($P < 0.0001$).

Food intake

Daily food intake (weight) varied with the portion size of the compulsory entrées, which was determined by the combination of their energy content and ED ($P < 0.001$; Table 3-5); the pattern of effects was the same for men and women. Participants consumed the greatest daily amount of food when served the largest entrées (standard energy content, reduced ED), and the least amount of food when served the smallest entrées (reduced energy content, standard ED). Daily food intake was not significantly different when participants consumed the entrées of equal portion size. Similarly, the amount of time it took participants to consume the entrées was greatest when served the largest entrées, and least when served the smallest entrées ($P < 0.0001$; data not shown).

Energy density

The overall ED of the discretionary foods consumed at each test meal was not significantly affected by the variations in the compulsory entrées. Thus, dietary ED for the entire day was determined by the combination of entrée energy content and ED ($P < 0.02$; Table 3-5). Dietary ED was highest when participants consumed the entrées of standard ED, followed by the entrée of reduced energy content and reduced ED, and lowest when participants consumed the entrée of standard energy content and reduced ED.

Table 3-5. Total daily food and energy intakes of participants

	Standard energy content		Reduced energy content		*P* values		
	Standard ED	**Reduced ED**	**Standard ED**	**Reduced ED**	**Energy effect**[1]	**ED effect**[2]	**Interaction**[3]
Men (n = 28)							
Discretionary food intake (g)	847 ± 65	687 ± 63	989 ± 77	893 ± 69	<0.01	<0.01	--
Discretionary energy intake (kcal)	1267 ± 92	1094 ± 91	1515 ± 105	1389 ± 91	<0.01	<0.01	--
Discretionary ED (kcal/g)	1.53 ± 0.08	1.66 ± 0.10	1.57 ± 0.07	1.65 ± 0.09	NS	NS	--
Daily food intake (g)	1844 ± 65[b]	2249 ± 63[c]	1622 ± 77[a]	1890 ± 69[b]	--	--	<0.001
Daily energy intake (kcal)	2837 ± 92	2664 ± 91	2518 ± 105	2392 ± 89	<0.01	<0.01	--
Daily ED (kcal/g)	1.54 ± 0.03[c]	1.18 ± 0.02[a]	1.57 ± 0.04[c]	1.27 ± 0.03[b]	--	--	<0.01
Women (n = 40)							
Discretionary food intake (g)	604 ± 41[b]	498 ± 41[a]	721 ± 42[c]	678 ± 44[bc]	--	--	<0.01
Discretionary energy intake (kcal)	969 ± 58[b]	807 ± 57[a]	1133 ± 60[c]	1083 ± 54[bc]	--	--	<0.01
Discretionary ED (kcal/g)	1.67 ± 0.08	1.71 ± 0.09	1.61 ± 0.06	1.69 ± 0.08	NS	NS	--
Daily food intake (g)	1300 ± 41[b]	1592 ± 41[c]	1162 ± 42[a]	1374 ± 44[b]	--	--	<0.001
Daily energy intake (kcal)	2069 ± 58[c]	1907 ± 57[b]	1830 ± 60[ab]	1780 ± 54[a]	--	--	<0.01
Daily ED (kcal/g)	1.60 ± 0.03[c]	1.19 ± 0.02[a]	1.58 ± 0.04[c]	1.29 ± 0.03[b]	--	--	<0.0001

All values are means ± SEMs. ED: energy density
[1] Significance of effects of entrée energy content. All effects were independent of entrée ED.
[2] Significance of effects of entrée ED. All effects were independent of entrée energy content.
[3] Significance of the interaction of the effects of entrée energy content and entrée ED.
[a,b,c] Means within the same row with different letters are significantly different

Ratings of hunger, fullness, and food characteristics

The factors of entrée energy content and ED independently influenced ratings of hunger, as assessed by the summary measure of the area under the curve of ratings across the day. In both men and women, there was a significant effect of entrée energy content on daily hunger ($P < 0.02$), indicating increased hunger when the entrées were of reduced energy content (373 ± 11 in men; 374 ± 8 in women) rather than standard energy content (338 ± 10 in men; 349 ± 8 in women). In addition, in women there was an independent effect of entrée ED ($P < 0.04$), indicating decreased hunger when the entrées were reduced in ED and thus larger in portion size (349 ± 10) rather than of standard ED (373 ± 8).

The summary measure of fullness was dependent on the interaction between entrée energy content and ED. In both men and women, daily fullness was significantly greater when the entrées were of standard energy content and reduced ED (i.e., largest portion) than when the entrées were of reduced energy content at either ED ($P < 0.04$). In addition, in women daily fullness in this condition was also greater than in the standard condition ($P < 0.01$). Ratings of thirst and nausea did not differ significantly by the experimental factors at any time point or over the day for either men or women (data not shown). Ratings of pleasantness of appearance, taste, and texture of the manipulated entrées did not differ significantly across conditions for men or women (data not shown). Mean ratings of pleasantness of taste for the breakfast, lunch, and dinner entrées, respectively, were 68 ± 2, 65 ± 2, and 69 ± 2 in men and 78 ± 1, 72 ± 1, and 70 ± 1 in women. For ratings of calorie content of the entrées, there was a significant effect of entrée energy content in both men and women for the lunch entrée and only in women for the dinner entrée. Men and women rated the calorie content higher in the standard-energy lunch entrées (57 ± 2 in men; 59 ± 2 in women) than the reduced-energy versions (51 ± 2 in men; 55 ± 2 in women; $P < 0.03$). Women rated the standard-energy entrées at dinner higher in calories (61 ± 2) than the reduced-energy entrées (58 ± 2; $P < 0.05$).

Subject characteristics

Analysis of covariance demonstrated that the relation between the experimental factors of entrée energy content and ED and the outcomes of daily energy intake was not significantly affected by participant age, height, weight, or body mass index. The outcomes were also not significantly affected by scores for dietary restraint, disinhibition, or hunger in women, nor by scores for dietary restraint and disinhibition in men. In men, the score for tendency toward hunger (20) significantly affected the relation between the experimental factors and the outcome of total energy intake over the day ($P < 0.01$). Daily energy intake increased with increasing score for tendency toward hunger only when the entrées smallest in portion size were consumed ($P = 0.006$).

Discharge questionnaire

Comments from the discharge questionnaire reported that 60 of 68 participants (88%) noticed that the manipulated entrées varied in the amount of food. Twenty-one participants (31%) noticed that the amount of vegetables in the entrées was different. When asked about the purpose of the study, 11 participants (16%) reported that the purpose was to determine how variations in the portion size or volume of entrées affected intake of other foods. No participants accurately discerned the purpose of the study to determine the effect of varying the energy content and ED of entrées on energy intake.

DISCUSSION

Consumption of pre-portioned entrées has been shown to be a beneficial strategy for weight loss, but little is known about how the characteristics of entrées, including energy content and ED, influence satiety. The purpose of this study was to investigate the effects of these characteristics of pre-portioned entrées on satiety and daily energy intake when a variety of discretionary foods was available. It was found that in non-dieting men and women, reducing both the energy content and ED of compulsory entrées led to decreases in daily energy intake even when various other foods could be consumed *ad libitum*. In addition, ratings of hunger and fullness were affected by the energy content and the ED of the entrées. These findings extend previous work showing the importance of energy content and ED in determining satiety, as well as demonstrating the utility of pre-portioned entrées in moderating energy intake and reducing consumption of discretionary foods. The results of this study suggest that both the energy content and ED of pre-portioned entrées affect daily energy intake and could influence the effectiveness of such foods for weight management.

Although reducing the energy content of the entrées led to an increase in consumption of discretionary foods, the compensatory response was incomplete, resulting in a decrease in daily energy intake. Furthermore, the 36% reduction in entrée energy content had a greater effect on daily energy intake than did the similar reduction in ED. These findings suggest that reductions in energy content (achieved by decreasing portion size) may be more beneficial in controlling intake than decreases in ED (achieved by maintaining energy content and increasing portion size). However, if entrées provide so little energy that they leave the consumer hungry, their effectiveness in reducing daily energy intake may be compromised by greater consumption of discretionary foods (11-13). In the present study, the decreased energy intake that resulted from reducing entrée energy content was accompanied by a significant increase in ratings of hunger across the day. Outside the lab, such increased hunger could translate into greater intake of tempting, high-ED foods; this would limit the effectiveness of reductions in energy content that are achieved simply by reducing the amount of entrée served.

One approach that might help control intake of additional foods is to provide entrées that are reduced in ED and provide a satisfying portion. We found that reducing the ED of pre-portioned entrées, thus increasing their portion size, led to a decrease in consumption of discretionary foods as well as a reduction in energy intake over the day. These results confirm several preloading studies showing that reducing the ED of equicaloric preloads results in an increase in fullness ratings (14,15,28) and a decrease in both consumption of other foods and energy intake at a meal (14-17,28). Multiple experimental studies have also shown that when an entrée is consumed *ad libitum,* reducing the ED by increasing the proportion of fruits or vegetables decreases meal energy intake (29-32). In the present study, reducing the ED of the compulsory entrées led to the consumption of a greater weight of food over the day and higher ratings of fullness. Furthermore, fullness ratings were greatest after consumption of the entrées largest in portion size (those with standard energy and reduced ED), suggesting that portion size was important in influencing fullness. It is likely that the decrease in energy intake from consuming entrées reduced in ED was due to enhanced satiety from eating a greater amount of food; thus, individuals felt fuller while consuming less energy over the day.

Comparing entrées that were matched in weight allowed the combined effects of energy content and ED to be separated from those related to portion size. Simultaneously reducing both the energy content and ED of the pre-portioned entrées, while maintaining the portion size, resulted in a decrease in daily energy intake of 16% in men and 14% in women. Previous research has shown that when portion size is held constant, reductions in the energy content and ED of preloads enhance satiety and decrease subsequent energy intake. One study found that meal energy intake was decreased by consuming a salad preload that was reduced in energy and ED but matched in portion size (16). Another investigation showed that consuming a compulsory breakfast and mid-morning snack that were reduced in ED but provided the same amount of food led to reductions in daily energy intake (33). Similarly, participants in the current study did not fully compensate for the reduction in entrée energy content when portion size was matched, even when given the opportunity to consume a variety of discretionary foods. Thus, reductions in ED may be beneficial in maintaining portion size and enhancing satiety when pre-portioned entrées are decreased in energy content.

Men and women had some differences in their response to the manipulation of entrée characteristics. In men, there were independent effects of entrée energy and ED on energy intake at individual meals and over the day, whereas in women there were independent effects of entrée energy at breakfast and lunch but an interaction of energy and ED at dinner and over the day. These differences may be attributable to the smaller magnitude of the changes in energy content and portion size of the women's entrées across the experimental conditions, since women received 70% of the amount of the compulsory entrées served to the men. Another reason for the difference may be the level of dietary restraint, which was significantly higher in women than men. An analysis of covariance, however, suggested that the restraint score did not have a significant influence on the relationship between the experimental conditions and daily energy intake. These findings suggest that further investigation is needed to determine how variations in the properties of foods may influence satiety and energy intake differently in men and women.

The results of this study indicate that modifying the characteristics of pre-portioned entrées led to decreased energy intake in non-dieting individuals even when a variety of other foods was available. Individuals who use pre-portioned entrées for the purpose of weight loss may respond differently to alterations in the characteristics of such foods. Dieters may experience even greater reductions in energy intake since they have an increased focus on limiting their intake of additional foods. To investigate this possibility, studies are needed in which individuals who are motivated to lose weight are provided with pre-portioned entrées that vary in energy content and ED. It also should be determined whether the findings from this one-day study would persist over a longer period. For long-term success at weight loss, it may be critical to consume foods that provide adequate energy and satisfying portions, thus avoiding feelings of hunger during caloric restriction. Previous research suggests that the effects of reductions in dietary ED on energy intake can be sustained over time. Two clinical trials found that following diets with larger reductions in ED resulted in greater weight loss after one year (34-35). Analyses from another trial of lifestyle modification to reduce hypertension showed that individuals with the greatest reductions in dietary ED had the largest decreases in body weight (36). Future studies are needed to investigate how modifying the characteristics of pre-portioned entrées affects long-term energy intake and weight management.

In conclusion, reductions in both the energy content and ED of pre-portioned entrées added together to decrease daily energy intake. Adding fruit and vegetables to decrease the ED of entrées allowed the portion size to be maintained while energy content was reduced, which contributed to enhanced satiety. The findings from this study suggest that in an environment that regularly exposes individuals to a variety of palatable high-ED foods, consuming pre-portioned entrées that are lower in ED can decrease discretionary energy intake. Since pre-portioned entrées are often used for weight management, more systematic exploration of the attributes of these foods is needed. It is crucial to provide consumers with a variety of options of pre-portioned entrées that are effective in enhancing satiety and moderating energy intake.

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CHAPTER 4

Study 3:

Assessment of satiety depends on the energy density and portion size of the test meal

Williams RA, Roe LS, Rolls BJ. Assessment of satiety depends on the energy density and portion size of the test meal. Under review.

INTRODUCTION

Addressing the problem of obesity requires dietary strategies to reduce energy intake in the face of opposing influences in the eating environment. One approach that could help curb overconsumption is to incorporate satiety-enhancing foods into meals (1). Studies show that eating a satiating food as a first course can decrease energy intake both at the main course and at the entire meal (2,3). It is unclear, however, whether these effects can be overridden by the other foods served at the meal. The purpose of the current study was to investigate whether increasing the energy density and portion size of the main course at a meal would counteract the effects of a satiating first course.

The satiety value of a food is typically assessed by consuming it as a preload or compulsory first course at a meal and measuring the effect on ad libitum energy intake at the subsequent test meal or main course (4). Previous research has demonstrated the utility of this paradigm in identifying characteristics of preloads that affect satiety (4,5), but little attention has been given to how attributes of the test meal influence satiety. An increase in either the energy density or portion size of a main course has been shown to result in greater ad libitum energy intake at a meal when no first course is served (6-11). Furthermore, simultaneous increases in both energy density and portion size lead to independent and additive increases in meal energy intake (6,7). These findings suggest that the characteristics of the test meal could have substantial effects when assessing the satiating properties of a preload.

The present study explored how alterations in the energy density and portion size of the test meal affect energy intake after consumption of a salad preload that has been shown to enhance satiety (2,12). In contrast to the typical method for assessing satiety, we served an unvaried preload and varied the properties of the subsequent test meal. It was hypothesized that after consumption of a satiating preload, increases in the energy density and portion size of the following test meal would independently influence energy intake at the test meal. This study also included two control conditions in which no preload was provided, in order to examine whether consumption of the preload influenced overall energy intake at the meal. It was hypothesized that compared to having no preload, consumption of a satiating preload would reduce energy intake at both the test meal and the total lunch (preload plus test meal).

METHODS AND PROCEDURES

Subjects

Women aged 20 to 45 years were recruited through advertisements in campus newspapers, flyers, and electronic newsletters. Respondents were eligible if they had no food restrictions, were not pregnant or breastfeeding, were not dieting, were not athletes in training, regularly ate three meals per day, were not taking medications affecting appetite, were willing to consume the study foods, and did not smoke. Potential subjects were excluded if they had a body mass index <18 or >40 kg/m^2; a score ≥20 on the Eating Attitudes Test (13), or a score ≥44 on the Zung depression scale (14).

A power analysis estimated that a sample of 38 women would allow the detection of a 50 kcal difference in meal energy intake with >80% power at a significance level of 0.05. A total of 53 women began the study; however, three women were excluded for failure to follow the study protocol. Of the 50 women who finished the study, data of three women were excluded for eating the entire test meal on two or more occasions. The data of one additional woman was excluded for having highly variable daily intakes that had undue influence on the outcomes according to the procedure of Littell, et al. (15). For this subject, the restricted likelihood distance (a measure of overall influence) in the mixed linear model was >2.1. Thus, the analyses included 46 women; their mean age was 25.4±0.8 y (range 20-44 y), their mean height was 1.63±0.1 m (range 1.51-1.76 m), and their mean weight was 62.5±1.5 kg (range 44.0-91.9 kg). Thirty-three subjects were normal-weight, 11 were overweight, and 2 were obese; the mean body mass index was 23.6±0.5

kg/m^2 (range 18.6-33.5 kg/m^2). Participants provided signed consent and were financially compensated for participation. Subjects were informed that the purpose of the study was to investigate eating behaviors at different meals. The Pennsylvania State University Office for Research Protections approved all aspects of the study.

Study design

This experiment used a crossover design with repeated measures within subjects. Once a week for six weeks, subjects came to the laboratory at lunchtime to eat a pasta test meal. At four meals the pasta was preceded by a compulsory salad preload and at two control meals no salad was served. The orders of the six experimental conditions were counterbalanced using Latin squares and were randomly assigned to participants. The pasta was varied between standard (100%) and increased (133%) levels of both energy density (ED; 1.25 or 1.66 kcal/g) and portion size (450 or 600 g); the composition of the test meals is shown in **Table 4-1**. The higher-ED version of the pasta was made by increasing the proportion of pasta, cheese, cream, and sauce and decreasing the proportion of puréed vegetables (broccoli, cauliflower, and tomato). In the two control meals, the pasta was served at the 100% and 133% levels of ED, but only the 133% level of portion size. The 100% portion of pasta was not served without a salad because of concerns that for some women this meal would provide an insufficient amount of food.

The unvaried preload at four meals was a low-energy-dense salad (300 g, 100 kcal, 0.33 kcal/g) consisting of lettuces, cucumber, tomatoes, carrots, fat-free Italian dressing, and parmesan cheese. Previous studies found this salad to enhance satiety (2,12). Subjects were required to consume the entire salad within 18 minutes and were served the pasta 20 minutes after the salad was served. During the 20-minute interval at the two meals in which no preload was consumed, participants were provided with magazines to read that did not contain any references to food or body weight. One liter of water was served with the pasta and both were consumed *ad libitum*.

All foods and beverages were weighed before and after meals. Energy and macronutrient intakes were calculated using information from a standard nutrient database (16) and food manufacturers. The salad preload and pasta test meal that were provided are shown in **Photograph 3**.

Table 4-1. Composition of the pasta test meals served at lunch[1,2]

	100% Energy density (1.25 kcal/g)		133% Energy density (1.66 kcal/g)	
	100% Portion size (450 g)	133% Portion size (600 g)	100% Portion size (450 g)	133% Portion size (600 g)
Energy (kcal)	563	750	747	996
Carbohydrate (% energy)	48.1	48.1	46.7	46.7
Protein (% energy)	18.1	18.1	17.4	17.4
Fat (% energy)	33.8	33.8	35.9	35.9
Fiber (g)	8.7	11.6	7.8	10.4

[1]Each version of pasta was served at one of the four meals that included a salad preload. At the two control meals that did not include a salad preload the pasta was served at the 100% and 133% levels of ED, but only the 133% level of portion size.

[2]Recipe information is available upon request to the corresponding author.

Photograph 3. Foods provided at the preload and test meal for this study.

Procedures

Participants were instructed to keep their food intake and activity level consistent on the day before each test day and to record this information to encourage compliance. In order to ensure subjects came to lunch at a consistent level of hunger and fullness, a standard breakfast of bagels and yogurt was served in the laboratory, which could be consumed as desired. Assessment showed that there were no significant differences in breakfast energy intake across conditions. Participants were asked to refrain from consuming any foods or beverages, other than water, between breakfast and lunch. Subjects came to the laboratory at scheduled meal times and were seated in individual cubicles.

Ratings of hunger, satiety, and food characteristics

Subjects used 100-mm visual analog scales (17) to rate their hunger and fullness before and after the pasta as well as before the salad, when served. The anchors for hunger were “not at all hungry” on the left and “extremely hungry” on the right, and the anchors were similar for fullness. Participants also used visual analog scales to rate characteristics of the pasta and salad. Upon being served each food, they took a bite and rated how pleasant the taste and texture were, how filling the serving of food would be, how the size of the serving compared to their usual portion, and how many calories were in the serving. For the taste and texture questions, the anchors were “not at all pleasant” on the left and “extremely pleasant” on the right. The anchors for the remaining questions were “not filling at all” on the left and “extremely filling” on the right, “a lot smaller” on the left and “a lot larger” on the right, and “no calories at all” on the left and “extremely high in calories” on the right, respectively.

Data Analysis

The data were analyzed using a mixed linear model with repeated measures (SAS System for Windows, version 9.3, SAS Institute, Inc., Cary, NC). The fixed factors in the model were pasta ED, pasta portion size, and study week. The main model analyzed the four conditions that provided the unvaried salad preload in order to determine the effect of changes in the ED and portion size of the test meal on the assessment of satiety. In accordance with the preloading paradigm, this analysis investigated the outcome of energy intake at the test meal. A second model assessed the effects of including the salad preload by analyzing the pairs of conditions that differed in the presence of the preload but provided the same test meal (either large portion of standard ED or large portion of increased ED). This analysis examined whether the consumption of a preload influenced energy intake at the test meal as well as overall energy intake at lunch, that is, when the energy content of both the preload and test meal was considered.

The study outcomes were food and energy intakes at the test meal, food and energy intakes at the entire lunch (preload plus test meal), and participant ratings of hunger, fullness, and food characteristics. Ratings of hunger and fullness after the test meal were adjusted for ratings at the start of the meal. Analysis of covariance was used to determine whether subject characteristics influenced the relation between the experimental factors and lunch intake. Results are reported as mean ± SEM and were considered significant at $p<0.05$.

RESULTS

Effects of increases in the energy density and portion size of the test meal

Test meal intake

Assessment of test meal energy intake in the four meals that included the salad preload showed that increases in the ED and portion size of the pasta test meal had independent effects (both $p<0.02$; **Table 4-2**). Serving the pasta that was 33% higher in ED increased test meal energy intake by a mean of 153±19 kcal and serving the portion of pasta that was 33% larger increased test meal energy intake by 40±16 kcal. Together these changes increased test meal energy intake by 187±21 kcal. Thus, after consumption of the salad, energy intake at the test meal was significantly influenced by both the ED and portion size of the test meal.

Evaluation of the weight of food consumed in these four meals showed significant effects of the portion size ($p<0.01$) but not the ED of the pasta test meal (Table 4-2). Food intake at the test meal was a mean of 32±11 g greater when the portion of pasta was increased by 150 g. After the salad, an increase in the portion size of the test meal thus significantly affected the weight of food eaten at the test meal.

Total lunch intake

Since the salad was not varied in the four meals that included a preload, the effects of test meal ED and portion size on the entire lunch (preload + test meal) were similar to those on the test meal alone. Thus, both the ED and portion size of the test meal influenced total lunch energy intake (**Figure 3-1**), and only the portion size of the test meal influenced the total weight of food consumed.

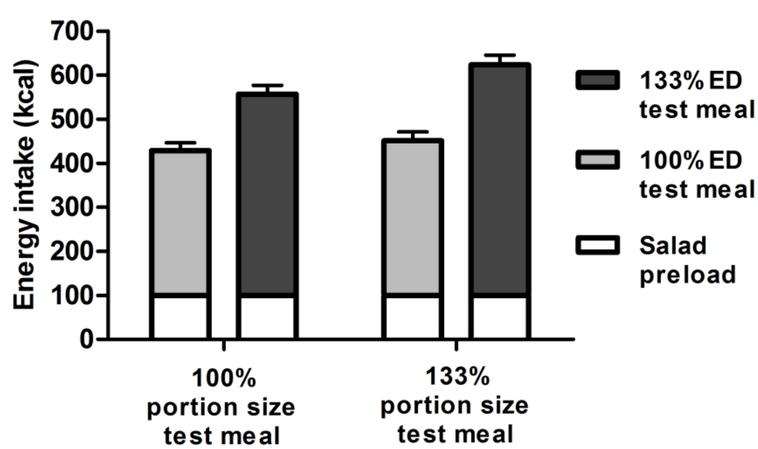

Figure 3-1. Mean (±SEM) energy intakes of 46 women who were served a test meal of pasta that was varied between 100% and 133% levels of both energy density (ED) and portion size, following a preload of salad that was not varied. Energy intakes at the test meal and at the entire lunch (salad + pasta) were independently increased by increases in the ED ($p<0.0001$) or portion size ($p<0.02$) of the pasta.

Table 4-2. Energy and food intakes (n=46)[1]

Preload	Salad	Salad	None	Salad	Salad	None	P values		
Test meal energy density	1.25 kcal/g	1.25 kcal/g	1.25 kcal/g	1.66 kcal/g	1.66 kcal/g	1.66 kcal/g	Effect of energy density of the test meal[2]	Effect of portion size of the test meal[3]	Effect of presence of the preload[4]
Test meal portion size	450 g	600 g	600 g	450 g	600 g	600 g			
Test meal intake									
Energy (kcal)	329 ± 18	351 ± 20	476 ± 16	457 ± 20	523 ± 22	649 ± 23	<0.0001	<0.02	<0.0001
Weight (g)	263 ± 14	281 ± 16	381 ± 13	275 ± 12	315 ± 13	390 ± 14	NS	<0.01	<0.0001
Total lunch intake[5]									
Energy (kcal)	429 ± 18	451 ± 20	476 ± 16	557 ± 20	623 ± 22	649 ± 23	<0.0001	<0.02	NS
Weight (g)	563 ± 14	581 ± 16	381 ± 13	575 ± 12	615 ± 13	390 ± 14	NS	<0.01	<0.0001

[1]All values are means ± SEMs.
[2,3]Significance of the independent effects of the pasta test meal energy density[2] and portion size[3] in the four meals that included the salad preload as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05).
[4]Significance of the independent effects of the presence of the salad preload in the conditions that included the same pasta test meal (600 g of either the 1.25 kcal/g version or the 1.66 kcal/g version), as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05).
[5]Total lunch intake includes the salad preload plus the pasta test meal.

Effects of consumption of a preload prior to the test meal

Test meal intake

Consumption of the salad preload significantly influenced energy intake of the test meal ($p<0.0001$; Table 4-2), as shown by comparing the conditions that differed in the provision of the preload but included the same test meal (either large portion of standard ED or large portion of increased ED). Having the salad reduced intake of the pasta test meal by a mean of 123±18 kcal compared to not having the salad; this decrease in test meal energy intake demonstrated that the salad enhanced satiety.

Evaluation of these conditions also showed that consumption of the salad influenced the weight of food consumed at the test meal ($p<0.0001$; Table 4-2). Consuming the salad preload decreased the weight of food consumed by a mean of 86±13 g. Having a 300 g salad thus significantly influenced the weight of food consumed at the test meal.

Total lunch intake

Across the conditions that differed in the provision of the salad preload but had the same test meal, consumption of the salad did not significantly influence total lunch energy intake ($p=0.21$; **Figure 3-2**). The 123 kcal reduction in energy from the pasta test meal combined with the 100 kcal addition from the salad preload resulted in no significant difference in total lunch energy intake compared to the control conditions (Table 4-2). Thus, participants compensated for the added energy from the salad by reducing intake of the test meal.

The provision of the salad significantly influenced the total weight of food consumed at the meal ($p<0.0001$; Table 4-2). Consumption of the salad preload increased the total weight of food consumed at lunch by a mean of 214±13 g. As expected, the 300 g increase in weight from the salad significantly influenced the total weight of food eaten at the meal.

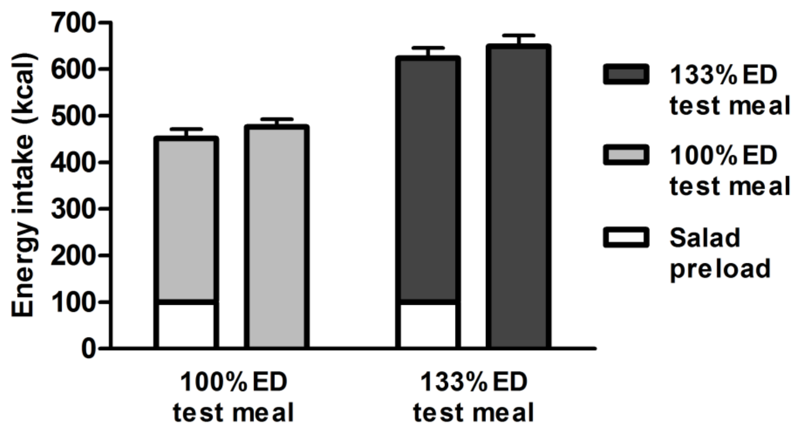

FIGURE 3-2. Mean (±SEM) energy intakes of 46 women who were served lunch meals that varied in the provision of the salad preload and included the same pasta test meal (600 g of either the 1.25 kcal/g version or the 1.66 kcal/g version). Consumption of the salad reduced test meal energy intake ($p<0.0001$) but did not significantly affect total lunch (salad + pasta) energy intake.

Ratings of hunger, satiety, and food characteristics

Upon arrival at the laboratory, subject ratings of hunger and fullness were not significantly different across conditions. At the end of the meal, hunger and fullness ratings depended on whether a preload was consumed. When the salad preload was eaten, ratings of hunger and fullness were not significantly influenced by the properties of the pasta test meal, despite substantial differences in food and energy intakes (**Table 4-3**). In contrast, consuming no salad resulted in higher hunger ratings after the pasta ($p<0.04$) but no significant difference in fullness ratings compared to having the salad.

Table 4-3. Ratings of hunger and fullness (n=46)[1]

Preload	Salad	Salad	None	Salad	Salad	None	P values		
Test meal energy density	1.25 kcal/g	1.25 kcal/g	1.25 kcal/g	1.66 kcal/g	1.66 kcal/g	1.66 kcal/g	Effect of energy density of the test meal[2]	Effect of portion size of the test meal[3]	Effect of presence of the preload[4]
Test meal portion size	450 g	600 g	600 g	450 g	600 g	600 g			
Hunger									
Before preload	63 ± 3	64 ± 3	65 ± 3	64 ± 3	60 ± 3	59 ± 4	NS	NS	NA
Before test meal	38 ± 3	39 ±1	69 ± 3	41 ± 3	42 ± 3	69 ± 3	NS	NS	<0.0001
After test meal	10 ± 2	9 ± 2	12 ± 2	7 ± 1	6 ± 1	9 ± 2	NS	NS	<0.04
Fullness									
Before preload	27 ± 3	28 ± 3	25 ± 3	27 ± 3	29 ± 3	29 ± 4	NS	NS	NA
Before test meal	58 ± 2	58 ± 3	22 ± 3	57 ± 3	56 ± 2	22 ± 3	NS	NS	<0.0001
After test meal	82 ± 2	85 ± 3	81 ± 2	86 ± 2	88 ± 2	84 ± 2	NS	NS	NS

[1]All values are means ± SEMs.

[2,3]Significance of the independent effects of the pasta test meal energy density[2] and portion size[3] in the four meals that included the salad preload as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05).

[4]Significance of the independent effects of the presence of the salad preload in the conditions that included the same pasta test meal (600 g of either the 1.25 kcal/g version or the 1.66 kcal/g version), as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05); NA = not applicable.

Participant ratings of pasta characteristics are shown in **Table 4-4**. When the meal included no salad, the mean ratings for pleasantness of taste were not significantly different for the standard- and increased-ED versions of the pasta (71±3 versus 73±3 mm; $p=0.69$). Participants' ratings of the amount of pasta they were served were significantly different for the two portions ($p<0.02$); the mean rating was 72±2 mm for the 100% portion and 81±2 mm for the 133% portion. There were no significant differences in ratings of the calorie content of the pasta even though there was a 33% difference in ED between the two versions. Ratings of characteristics of the salad, which was not varied, did not differ significantly across conditions (data not shown); the mean rating for pleasantness of taste was 75±1 mm.

Influence of subject characteristics

Analysis of covariance showed that the relationships between the experimental factors and the outcomes of energy and food intakes were not significantly influenced by participant body mass index, age, height, or weight.

Table 4-4. Ratings of characteristics of the test meal (n=46)[1]

Preload	Salad	Salad	None	Salad	Salad	None	P values		
Test meal energy density	1.25 kcal/g	1.25 kcal/g	1.25 kcal/g	1.66 kcal/g	1.66 kcal/g	1.66 kcal/g	Effect of energy density of the test meal [2]	Effect of portion size of the test meal [3]	Effect of presence of the preload [4]
Test meal portion size	450 g	600 g	600 g	450 g	600 g	600 g			
Taste	55 ± 4	58 ± 3	71 ± 3	66 ± 3	64 ± 3	73 ± 3	<0.01	NS	<0.001
Texture	51 ± 4	52 ± 3[a]	66 ± 3[b]	61 ± 3	63 ± 3[b]	66 ± 3[b]	<0.01	NS	Interaction[5] <0.01
Filling	88 ± 2	91 ± 2	88 ± 2	91 ± 2	92 ± 1	88 ± 2	NS	NS	<0.02
Size	73 ± 2	81 ± 2	78 ± 2	72 ± 3	80 ± 2	81 ± 2	NS	<0.001	NS
Calories	69 ± 2	70 ± 3	69 ± 3	70 ± 2	74 ± 2	71 ± 2	NS	NS	NS

[1]All values are means ± SEMs. Ratings were assessed prior to consumption of the pasta test meal.
[2,3]Significance of the independent effects of the pasta test meal energy density[2] and portion size[3] in the four meals that included the salad preload as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05).
[4]Significance of the independent effects of the presence of the salad preload in the conditions that included the same pasta test meal (600 g of either the 1.25 kcal/g version or the 1.66 kcal/g version), as assessed by a mixed linear model with repeated measures. NS = not significant (p>0.05).
[5]Significance of the interaction of the effects of the presence of a salad preload and the energy density of the pasta test meal in the conditions that included the same test meal (600 g of either the 1.25 kcal/g version or the 1.66 kcal/g version), as assessed by a mixed linear model with repeated measures. Means in the same row with different superscript letters are significantly different.

DISCUSSION

The consumption of satiety-enhancing foods is one dietary strategy that could help people curb overconsumption to manage their weight. It is not clear, however, whether other foods that are readily available in the current obesogenic environment influence how satiety-enhancing foods affect energy intake. The present results showed that following a salad preload, increases in the energy density or portion size of the test meal led to independent increases in energy intake at the test meal as well as at the entire lunch (preload plus test meal). Compared to having no salad, consuming the salad decreased energy intake at the test meal and thus was shown to enhance satiety; having the salad did not, however, affect total energy intake at lunch. This study demonstrated that the effect of satiety-enhancing foods can be influenced by the ED and portion size of the other food at the meal.

Research on satiety has focused on the way that properties of a preload affect subsequent intake at an unvaried test meal (4,5), but it is possible that the characteristics of the test meal itself could markedly affect satiety assessment. This concern has been raised previously (18,19), yet the influence of the test meal has undergone little systematic investigation. A few studies have explored the effects on satiety of varying the variety (20-22), palatability (23,24) or macronutrient content (25) of the test meal. What has not been investigated, however, is how the large portions of energy-dense foods that are characteristic of the present eating environment influence the effect of a food on satiety. The findings from our study show that after the satiety-enhancing preload, increasing either the ED or portion size of the pasta test meal increased energy intake at the test meal. Thus, the same preload can have very different effects on satiety (a range of 187 kcal in this study), depending only on the properties of the subsequent test meal. This suggests that the current paradigm for satiety assessment should be broadened to include consideration of characteristics of the test meal in addition to the preload.

It would also be advantageous to extend the assessment of satiety beyond effects on test meal intake to include whether satiety-enhancing foods decrease energy intake at the entire meal and thus help curb overconsumption. To evaluate this, intake needs to be compared at similar meals with and without the preload. This comparison was made in two previous studies, which found that a similar low-ED salad reduced total meal energy intake by 50 to 100 kcal (2,12). In the present study, the reduction of 23 kcal at lunch was smaller than anticipated and did not reach statistical significance. The discrepancy in meal energy intake may have been due to differences in the subjects that were tested, even though all three studies tested women. Another possibility is the difference in the food that was served at the test meal. Although a pasta test meal was used in all three studies, the pasta in the current study differed in shape, form, ED, and portion size from the other test meals. Together, these differences in subject characteristics and the test meal could have influenced the compensatory response, since the present study found compensation for the salad energy, but not the expected reduction in lunch energy intake. These results indicate the importance of assessing intake at the entire meal and suggest the benefit of including a control condition when evaluating how satiety-enhancing foods moderate energy intake at a meal.

Inconsistencies in the identification of satiety-enhancing foods have been noted in the literature (5). The present finding that the assessment of satiety is markedly affected by the ED and portion size of the test meal, together with previous research showing that test meal properties such as variety, palatability, and macronutrient content can influence satiety (20-25), provides a possible reason for these inconsistencies. It could be useful in resolving these discrepancies if the satiety paradigm was further refined, taking into account the properties of the test meal. Food manufacturers should be aware that their satiety-enhancing products may have limited applicability if the products are not tested using meals that are comparable to those that consumers experience on a daily basis (26,27). Although a recent study suggests that consumers are adept at appropriately interpreting satiety claims (28), consideration of the influence of the test meal on satiety assessment could also help address concerns that these claims could be misleading and lack utility (29-31).

An interesting finding from this study was that despite the large differences in energy intake across conditions, participant ratings of fullness were not affected by the ED or portion size of the test meal. In addition, participants rated the two pasta versions as similar in calorie content, suggesting that they did not notice the differences in pasta ED. This lack of sensitivity to the properties of foods that led to increased energy intake could hinder the efforts of individuals to control their energy consumption. The current study did not include dieters, however, and it is possible that individuals who are monitoring their intake may respond differently to alterations in ED and to consuming satiety-enhancing foods. Our results also showed that weight status did not influence the relationship between the properties of the test meal and energy intake, but it would be informative to test this design in a larger sample of obese individuals. Since foods that enhance satiety are consumed by both men and women, additional research should determine whether men respond similarly to the consumption of satiety-enhancing foods when faced with energy-dense foods and large portions.

Although the incorporation of satiety-enhancing foods into meals could be a beneficial strategy to help moderate energy intake for weight management, this study emphasizes the importance of the eating environment in which such foods are consumed. After consumption of the salad, overall energy intake at the meal was affected by both the ED and the portion size of the rest of the meal. Because of the strong environmental influences affecting energy intake, individuals may benefit from consuming multiple satiety-enhancing foods across the day in order to moderate energy intake. Additional investigation is needed not only to find foods that enhance satiety but also to determine how best to incorporate these foods into diets to effectively reduce energy intake (1,32). While satiety-enhancing foods help to moderate energy intake, their effects can be influenced by the availability of large portions of energy-dense foods.

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CHAPTER 5

Conclusions

SUMMARY OF FINDINGS

The objective of the studies presented in this dissertation was to extend the research on three strategies that can moderate energy intake: reducing the energy density of foods, consuming pre-portioned entrées, and incorporating satiety-enhancing foods into meals.

Study 1 investigated the effects on energy intake of reducing entrée energy density using three different methods (decreasing fat, increasing fruits and vegetables, and adding water). Entrées at each meal were reduced in energy density by 20% and were provided along with unmanipulated side dishes; all foods were consumed ad libitum. All three methods decreased daily energy intake compared to the standard energy density entrées. Across the reduced energy density conditions, however, decreasing fat led to the greatest decrease in energy intake over the day, but not at individual meals. Daily summary ratings of hunger and fullness were similar even though energy intakes differed across conditions. The curves for cumulative energy consumption over the day were also similar across the methods of energy density reduction.

Study 2 examined how alterations in the energy content and energy density of pre-portioned entrées combine to influence daily energy intake. Each meal included a compulsory, manipulated pre-portioned entrée followed by an assortment of unmanipulated discretionary foods that were consumed ad libitum. The pre-portioned entrées varied in energy content and energy density between a standard level (100%) and a reduced level (64%). The entrées that were standard in both energy content and energy density were equal in portion size to those that were reduced in both energy content and energy density. In men, reductions in the energy content and energy density of pre-portioned entrées had independent effects on daily energy intake. In women, these entrée characteristics also had independent effects on energy intake at breakfast and lunch, but the characteristics interacted at dinner and for the entire day. For both men and women, comparison of the entrées of equal portion size showed that simultaneously reducing the energy content and energy density decreased daily energy intake. Summary ratings of hunger and fullness across the day also varied according to entrée characteristics. Daily hunger ratings were higher when entrées were of reduced energy content instead of standard energy content. In comparison, daily fullness ratings were greater when entrées were of standard energy content and reduced energy density (i.e. largest portion) rather than when entrées were of reduced energy content at either energy density level.

Study 3 tested the effect on meal energy intake of varying the energy density and portion size of food eaten after a preload shown to promote satiety (1, 2). A large portion of a low-energy-dense salad preload was served prior to a manipulated pasta test meal that was consumed ad libitum. The test meal varied in energy density and portion size between a standard level (100%) and an increased level (133%). On four days the salad preload was served and on two control days a salad was not served. Following the salad preload, increasing the energy density or portion size of the pasta test meal independently increased energy intake at the test meal as well as at the lunch meal (salad plus pasta). In addition, simultaneously increasing the energy density and portion size of the test meal led to an even greater effect on energy intake than either factor alone. Compared to not having a salad, eating the salad decreased energy intake at the test meal, but not at the lunch meal. Even with very different energy intakes, ratings of hunger and fullness did not vary according to the characteristics of the test meal.

All three studies in this dissertation support prior research showing that variations in energy density have robust effects on energy intake (3). Studies 1 and 2 showed that reductions in the energy density of entrées by a variety of methods, including incorporating fruits and vegetables (studies 1 and 2), decreasing fat (study 1), and adding water (study 1) decrease energy intake. In comparison, study 3 showed that after a compulsory, satiety-enhancing food, increasing the energy density of a main dish increases energy intake. The results from these studies can inform dietary recommendations for the public as well as areas for research and product development for food manufacturers.

STUDY 1: COMPARISON OF THREE METHODS TO REDUCE ENERGY DENSITY: EFFECTS ON DAILY ENERGY INTAKE

Implications

Reductions in entrée energy density by three different methods (decreasing fat, increasing fruits and vegetables, and adding water) all substantially decreased energy intake at meals and over the day. Despite the large differences in energy intake, however, daily summary ratings of hunger and fullness were not significantly different after consumption of the standard- and reduced-energy-dense entrées. The results from this study are consistent with research showing that reductions in entrée energy density by various methods decrease energy intake without affecting ratings of hunger and fullness (4-11). These findings indicate that individuals can use a variety of diet compositions to reduce dietary energy density in order to moderate energy intake.

Across the reduced energy density conditions, consumption of the decreased-fat entrées resulted in a greater reduction in daily energy intake, lower intake of fat, and higher intake of protein than the other two methods. Previous studies found that alterations in fat content did not influence energy intake when energy density was matched (5, 12). In comparison, variations in protein content when energy density was held constant decreased energy intake in some studies (13, 14), but not in others (12, 15). It is possible that reductions in energy density by decreasing fat (and also increasing protein) could have greater effects on energy intake than other methods, but additional studies are needed.

The finding that all three methods decreased energy intake provides flexibility for individuals who are interested in reducing dietary energy density and lowering energy intake. Since single methods of energy density reduction can alter the sensory properties of foods, not all foods may be suitable for reductions in energy density by each method. For example, decreasing fat reduces moistness whereas adding water increases moistness. This suggests that for someone who prefers moister foods, adding water to recipes may be preferred. Individuals who are concerned about health may choose to reduce energy density by incorporating fruits and vegetables because it would increase consumption of these foods and could improve diet quality. A combination of methods could also be used to minimize sensory differences and thus increase the number of foods that could be reduced in energy density by the various methods. One example would be to decrease fat and increase fruit when baking by substituting oil with applesauce. Either single methods or a combination of methods can thus be used to reduce energy density according to individual preferences and the type of food being modified.

Food manufacturers can also use the findings from this study to inform product development. These companies could produce foods that are lower in energy density using a variety of methods, depending on the type of food and constraints related to cost, packaging, etc. Manufacturers could also use a combination of methods in order to lessen variations in sensory characteristics as a result of different methods of energy density reduction.

Strengths, limitations, and future research

Study 1 was the first to compare different methods of energy density reduction and their effects on energy intake. Reductions in energy density by a variety of methods have been shown to decrease energy intake (4-11, 16-19), yet previous research has not determined whether the effects on intake differ according to the method. Because of the various biological processes that likely influence intake when energy density is reduced, some researchers have proposed that the methods would differ in their effects on energy intake over the day (20-23). In particular, it has been suggested that reductions in energy density by decreasing fat or increasing fruits and vegetables would have effects on intake that would persist beyond one meal, whereas reductions in energy density by adding water would only have transient effects on energy intake (20-23). Although this study found that the three methods had similar curves for cumulative energy consumption over the day, it is possible that the methods would differ in their effects on energy intake over multiple days. Engagement of different biological processes in combination with other factors that influence intake when energy density is reduced would be expected to contribute to these effects. Investigation of these three methods and their effects on energy intake over longer periods could provide valuable information on eating behavior.

Since this was a satiation study, it measured ad libitum intake of entrées that were reduced in energy density by three single methods. When foods are consumed ad libitum, intakes will vary between people, making it difficult to compare intakes to biological markers or other physiological mechanisms (24). Another way of investigating how the various methods influence intake would be to measure satiety using the preloading paradigm (25). With this design, participants would be required to consume a specified amount of entrée prior to receiving a test meal with other foods that could be consumed ad libitum. This design could limit the influence of potential confounding variables such as differences in palatability or other sensory characteristics. For example, a previous study showed that varying the palatability of a preload did not affect the measurement of satiety, defined by either ratings of hunger or intake at the test meal (26). With the use of the preloading paradigm, consumption of the manipulated entrée would be standardized across participants, allowing the various methods of energy density reduction to be compared concerning their effects on hormonal responses and subsequent energy intake at the test meal.

The fiber content of fruits and vegetables is one of the reasons that increasing these foods has been suggested to have persistent effects on energy intake beyond one meal. In this study, comparison of entrées that were increased in either fruits and vegetables or water provided an assessment of whether the incorporation of fruits and vegetables into foods decreased energy intake because of increases in fiber content. The differences in fiber content in this study were small, however, and it is possible that larger differences in fiber content (27, 28), in addition to an increased amount of chewing required (28, 29), could differentially influence energy intake between these methods.

The use of single methods of energy density reduction made it challenging to match the sensory properties of the entrées. As a result, there were some differences in moistness and palatability, but these differences were not consistent across entrées or within methods. Variations in entrée sensory characteristics did not always correspond to differences in intake, and associations between these variables were not significant. This study may not have been sufficiently powered to detect the influence of changes in sensory properties on intake, suggesting that additional research should examine how the sensory attributes of single methods of energy density reduction affect intake. Future research should also investigate how these methods combine to influence consumption as well as biological processes.

STUDY 2: EFFECTS OF ENERGY CONTENT AND ENERGY DENSITY OF PRE-PORTIONED ENTRÉES ON ENERGY INTAKE

Implications

Reductions in either the energy content or energy density of pre-portioned entrées decreased daily energy intake, even when a variety of discretionary foods was available. Energy intake from discretionary foods varied according to the entrée characteristics, however, in that it was higher when entrées were reduced in energy content but was lower when entrées were reduced in energy density. Reduced energy content entrées also increased summary ratings of hunger over the day, whereas reduced energy density entrées increased summary ratings of fullness over the day. The greatest increase in fullness ratings was found when entrées were reduced in energy density and provided the largest portion. These findings are consistent with previous work showing that while low energy preloads led to a higher energy intake at the test meal and an increase in hunger ratings, total meal energy intake (preload + test meal) was lower when preloads contained less energy (30-32). If entrées leave people feeling hungry, they may more be likely to consume excessive energy from the array of palatable, energy-dense foods that are readily available in the current eating environment, which could also lead to greater total meal energy intakes. In comparison, consumption of reduced-energy-dense preloads has been shown to decrease both test meal and total meal energy intakes and to increase fullness ratings (19, 33). This suggests that people could be less likely to consume excessive energy from discretionary foods if entrées are reduced in energy density and thus are more satiating. These findings indicate that variations in the energy content and energy density of pre-portioned entrées could influence the utility of these foods for weight management.

Comparison of entrées that were matched in portion size showed that reductions in energy content and energy density also combined to decrease daily energy intake. This suggests that when entrée energy content is reduced, providing the same portion may maintain levels of hunger and fullness and thus decrease energy intake. Previous research has shown that compulsory foods that provided the same portion but were reduced in energy density and energy content led to lower energy intakes at the test meal (1) and over the day (34). Together, these results indicate that maintenance of portion size when energy content is reduced could influence the effectiveness of pre-portioned entrées in moderating energy intake.

Dietary energy density over the day was determined by the energy density of the entrées, and was lower when the reduced-energy-dense entrées were consumed. Research has shown that consumption of lower-energy-dense diets is associated with greater weight loss and lower energy intake (35, 36). Clinical trials have also shown that reductions in dietary energy density are associated with greater reductions in body weight (37, 38). These data suggest that consumption of entrées that are low in energy density could help individuals moderate energy intake.

The compulsory entrées were reduced in energy density by increasing the fruit and vegetable content. Ad libitum consumption of entrées reduced in energy density using this method has been shown to decrease energy intake at meals and over the day (17, 39). In addition to decreasing energy intake, entrées that contain more fruits and vegetables could increase diet quality and help individuals meet recommended intakes of these foods.

Food manufacturers should continue to develop entrées that vary in energy content, energy density, and portion size. Some people may prefer to consume a single entrée that contains sufficient energy content, provides a large portion, and increases fullness. If the entrée is nutritionally complete and leaves a person feeling satisfied, consumption of this food may help to decrease intake of other high-energy-dense foods at the meal and thus manage overall energy intake. Individuals who consume entrées for their convenience and are not concerned about energy content might prefer entrées that provide more energy. Depending on the other foods available at the meal, however, someone consuming an entrée with a moderate to high energy content may end up consuming more energy than needed (30-32). On the other hand, dieters might prefer entrées that are lower in both energy content and energy density but maintain portion size because these entrées could decrease energy intake without increasing hunger.

Strengths, limitations, and future research

Little is known about how characteristics of solid, pre-portioned entrées influence energy intake and ratings of hunger and fullness. Furthermore, most studies that have investigated properties of foods such as the energy content and energy density have used foods typically served as a first course (1, 30-32, 40, 41). Study 2 was therefore one of the first studies to examine the effects of varying the energy content and energy density of pre-portioned entrées. As a result of varying the energy content and energy density, the entrées varied in portion size. Even though these entrées provided a range of characteristics that were similar to commercially available products, only a few possible combinations of energy content, energy density, and portion size were tested. Investigation of a greater range and various combinations of entrée characteristics is needed in order to determine how alterations in entrée characteristics influence intake and ultimately weight loss.

Determination of energy provision was based on nationally representative data (42) and the entrées were meant to provide approximately 50-60% of daily energy needs. In this study, women received 70% of the energy that men received for all of the foods provided (pre-portioned entrées and the discretionary foods) since women typically have lower energy needs. It is possible that the differences in the effect of entrée characteristics on energy intake between men and women could be related to discrepancies between national data and the population being studied. For example, the energy needs and physical activity levels of the women in this study may have been higher than what was estimated from the national data. Thus, if women had received a greater proportion of the energy received by men, the effects of entrée characteristics on energy intake might have been more similar. Another reason for the differences between men and women could be a result of the women's entrées having smaller differences in the magnitude of the change in energy content and portion size than the men's entrées. The net differences in energy content and portion size over the day would thus be smaller for the women than for the men, which could have resulted in the differences in effects on energy intake at dinner and over the day.

Subject characteristics were not found to influence the relationship between the experimental condition and intake. This study included mostly normal weight participants who were not dieting, however, and it is possible that individuals who are dieting might respond differently when consuming pre-portioned entrées. For example, people who are dieting would be more likely to restrict their intake of other foods, especially higher-energy-dense foods, and thus might experience even greater reductions in energy intake. Additional studies should examine whether individuals who are actively trying to lose weight respond similarly to consumption of pre-portioned entrées that vary in energy content and energy density.

Future research should explore how variations in the characteristics of pre-portioned entrées influence intake over a longer period. It is important to determine whether the effects on intake found over one day in this study would persist over multiple weeks since weight loss requires a sustained decrease in energy intake. Another consideration that should be investigated is whether pre-portioned entrées are being consumed within a setting that is representative of a weight loss program or the obesogenic environment. Weight loss programs encourage consumption of pre-portioned entrées in combination with specified servings of fruits, vegetables, and dairy, in order to limit exposure to other foods (43-54). These entrées therefore provide structure and minimize decisions related to the amount of food to eat. It is possible that variations in the characteristics of pre-portioned entrées may not have as great of an effect on energy intake if they are consumed within a reduced-energy diet with specific guidelines. In contrast, if pre-portioned entrées are not consumed within the context of a weight loss program, variations in their characteristics might have even greater effects on intake. People are exposed to a variety of energy-dense foods in the current eating environment, and entrées that reduce hunger, increase fullness, and decrease intake of discretionary foods might lead to more beneficial effects on daily energy intake.

STUDY 3: ASSESSMENT OF SATIETY DEPENDS ON THE ENERGY DENSITY AND PORTION SIZE OF THE TEST MEAL

Implications

The effect of a satiety-enhancing food was influenced by the energy density and portion size of the other food served at the meal. These properties worked together to affect intake, such that an increase in both energy density and portion size led to a greater energy intake than an increase in either factor alone. Even though there were substantial differences in energy intake across conditions, ratings of fullness did not vary according to the properties of the test meal. These results are consistent with previous research showing that increasing the portion size or energy density of an ad libitum main course results in a higher energy intake without changing ratings of fullness (6-8, 55, 56). This indicates that the ability of a preload to decrease energy intake could vary depending on the properties of the foods at the subsequent meal. These findings highlight the importance of considering the meal environment in which satiety-enhancing foods are consumed.

Compared to not having a salad (control condition), eating the salad preload decreased test meal energy intake but did not influence total lunch energy intake (preload + test meal). This finding differs from two previous studies that served similar salad preloads but found reductions in both test meal energy intake and overall energy intake at lunch (1, 2). The differences across studies may be a result of different subjects and test meals that varied in several characteristics. Although reducing energy intake at the subsequent meal is beneficial, this alone does not curb overconsumption. In the context of weight management, reduction in total meal energy intake is necessary in order to moderate energy intake and thus should be considered when measuring the effects of satiety-enhancing foods. These findings also emphasize the usefulness of including a control condition when assessing the effects of a preload on energy intake. It is valuable to know whether a satiety-enhancing food has an added benefit of reducing overall energy intake compared to when this food is not consumed.

Food manufacturers can use the findings from this study to inform research and product development. If they are interested in comparing two or more foods and their effects on satiety, then the standard preloading paradigm can be used to distinguish among these foods. This comparison would show which products or components of foods have greater effects on satiety and thus lead to larger reductions in subsequent energy intake. These satiety-enhancing products may have limited applicability, however, if products are not tested using meals that are similar to those experienced by consumers on a regular basis (57, 58). In contrast, if the interest is in establishing satiety claims related to overall energy intake at a meal, then caution should be used when interpreting results that have not included a control condition.

Although concerns have been raised over whether satiety claims are misleading (59-61), research has suggested that people are able to properly interpret these claims (62). Individuals can use satiety-enhancing foods to moderate energy intake, but the large portions and energy-dense foods in the current eating environment may alter the effects of these foods. Because of these environmental influences, consumption of satiety-enhancing foods at multiple eating occasions over the day may be advantageous in order to curb overconsumption.

Strengths, limitations, and future research

There are many inconsistencies within the satiety literature concerning the types and properties of foods that enhance satiety (63). One possible solution to help resolve these discrepancies would be to better characterize the definition of satiety, including taking into consideration how the attributes of the test meal influence the satiating effect of a food. A few studies have shown that energy intake at the test meal is affected by the characteristics of this meal, including variations in palatability (32, 64), variety (41, 65, 66), and macronutrient content (67). Despite a great deal of research showing that alterations in the energy density and portion size of foods can influence intake, alterations in these characteristics of the test meal have not been investigated. Thus, study 3 varied the energy density and portion size of the test meal and provided evidence to support previous findings that the properties of the test meal influence the satiating effects of a preload. The results from this study indicate that more research is needed on the influence of test meal characteristics on satiety assessment (68, 69).

Study 3 tested two levels of energy density and portion size of the test meal. Because the present environment provides foods that are higher in energy density and larger in portion size than the levels used in this study, further research should explore how satiety is affected by different levels of these test meal properties. Provision of a test meal that is higher in energy density may lead to greater increases in energy intake (6-8). In comparison, although large portions increase energy intake (7, 8, 55, 56, 70, 71), people may not continue to eat more if the portion of the test meal becomes too large.

Participants in this study were not dieting, and it is possible that individuals who are monitoring their intake may differ in their response to consuming satiety-enhancing foods. For example, if people are restricting their intake they may eat less at a test meal that varies in energy density and portion size. On the other hand, if the test meal provided palatable, energy-dense foods that were considered “forbidden” foods, dieting individuals might be more likely to consume larger amounts at the test meal. Although this study did not find that weight status affected energy intake, it is also possible that individuals who are obese would respond differently to the consumption of satiety-enhancing foods and changes in test meal properties.

Since satiety-enhancing foods are consumed by both men and women, future studies should establish whether men respond differently when these foods are eaten prior to a test meal that varies in energy density and portion size. It would also be interesting to determine whether the presence of satiety claims on a food influence its effect on intake at a test meal that differs in these characteristics. After eating a food with a satiety claim, some individuals may be more likely to overeat at a test meal that varies in energy density and portion size or other characteristics.

Consumption of satiety-enhancing foods is a dietary strategy that can be used to help individuals moderate energy intake and manage weight. Because of the beneficial effects of these products, additional research should focus on developing foods that enhance satiety. Exploration is also needed on how to most effectively incorporate these foods into diets (72, 73). For instance, in order to achieve the greatest reductions in energy intake, multiple satiety-enhancing foods may need to be incorporated into the diet over the day.

FINAL CONCLUSIONS

Given the present rates of overweight and obesity, dietary strategies are needed that can help individuals curb overconsumption. This dissertation included three studies that addressed dietary approaches to moderate energy intake: reductions in energy density (Study 1), consumption of pre-portioned entrées (Study 2), and consumption of satiety-enhancing foods (Study 3). The results from these studies emphasize how variations in energy density affect energy intake. Studies 1 and 2 demonstrated that reductions in energy density by a variety of methods can decrease energy intake, including in the context of pre-portioned entrées. Study 3 indicated how an eating environment that is characterized by large portions of energy dense foods can influence the effects of satiety-enhancing foods. This dissertation has expanded upon previous work, and its findings can be used to inform future research. These three studies provide practical information on dietary strategies that can be used to reduce energy intake and potentially aid weight loss and weight maintenance endeavors.

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Appendix A

Telephone screening questionnaire

(Study 1)

Pre-screening Questionnaire

Date:
Age: ___________ Date of Birth: _____________
Height: _________ Weight:

-
Do you smoke? No Yes

Are you currently taking any prescription or "over the counter" medications regularly? No Yes
If yes, what?____

Are you currently dieting to gain or lose weight? No Yes
Are you an athlete in training? No Yes
Do you have any food allergies or intolerances? No Yes
Do you have any sugar/sweetener or sodium restrictions? No Yes
Do you have any food restrictions related to religious practices? No Yes

Are you a vegetarian? No Yes
If no, are there any meats that you exclude from your diet?___________

Do you like and are willing to eat:

-Oatmeal with peaches and cinnamon	yes	no
-Taco casserole with pasta, ground beef, red pepper, tomato, onion, & Mexican seasoning	yes	no
-Chicken and rice casserole with broccoli, peas, carrots, & mushrooms	yes	no

Do you regularly eat 3 meals per day? No Yes
If no, what is your usual daily pattern of meals?

Would you be willing to refrain from eating after 10:00 pm the evening before test sessions? No Yes

Would you be willing to refrain from drinking alcoholic beverages the day before each test session? No Yes

Are you pregnant or breast feeding? No Yes

Where did you hear about the study?__________________________________

Have you participated in any other studies in our lab? No Yes
If yes, what study and when? ____

Are you eligible to work in the United States: Yes No

Are you a: _____Undergraduate semester standing:__________ major:____________
_____ Graduate major:______________
_____Penn State Staff
_____State College Resident

If criteria are satisfied, take their name and ask them to come to the lab to fill out questionnaires and to have their weight & height recorded.

Name: _________________ Phone: ________________ Appointment: ___________________

Appendix B

Questionnaire consent form

(Study 1)

INFORMED CONSENT FORM FOR BIOMEDICAL RESEARCH
Prescreening Questionnaire

Title of Investigation: Perceptions of Different Tastes - 5

Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
226 Henderson Bldg. Penn State University
University Park, PA 16802
EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

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IRB# 32887 Doc. # 1001
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 03-19--2010 JDM
Expiration Date: 03-17-2011 JDM

Purpose of today's visit: To determine if you meet the criteria to be a participant in this laboratory's human ingestive behavior studies.

Procedure: It will take you approximately 45 minutes to complete this packet of questionnaires, taste samples of food and have your height and weight measured. These questionnaires are to determine whether or not the studies conducted at our laboratory are appropriate for you. You will be weighed and your height measured. You will also be asked to rate the tastes of different foods. Our studies require a considerable amount of preparation and, in order to assure reliable results for the studies, it is very important that participants fulfill all criteria of the studies.

Because of strict subject criteria, it may be determined that we cannot have you participate in the current study. There are a variety of reasons why an individual may not be chosen for a particular study. Often the number of responses from potential participants exceeds the number of individuals needed for the study. If you are not chosen to participate at this time, your information will be kept on file and you may be called later to participate in another study.

Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions are personal and might cause discomfort.

If, as a result of filling in the questionnaires, you feel that you would benefit from psychological assistance, or individual counseling, you may contact:

Psychological Clinic of the Penn State University
314 Moore Building
University Park, PA 16802
Phone: (814) 865-2191

Your responses to the questionnaires will be reviewed by a staff member. If any of the questionnaires indicate that you may benefit from professional treatment (i.e. counseling or physician's care), you will be notified by a staff member via telephone within 3 days of review of your questionnaire packet.

Benefits: If you qualify to become a participant in a study at the Human Ingestive Behavior Laboratory, you will be contributing to our understanding of human eating behavior.

Contact Person: Jennifer Meengs
226 Henderson Building
University Park, PA 16802
814-863-8482

Confidentiality: Your responses on the questionnaires will remain confidential. The Pennsylvania State University's Office for Research Protections and Institutional Review Board, and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this project.

Voluntary Participation: Your participation in the research is voluntary. You do not have to answer any questions you do not wish to answer. Your participation is voluntary and you are free to withdraw your consent and terminate your participation at any time. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

Right to Ask Questions: Please contact Jennifer Meengs at 863-8482 with questions, complaints or concerns about the research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact the Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

Injury: In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

To the best of your knowledge and belief, you have no physical condition or dietary requirements, such as food allergies or food restrictions, which would increase your risk for participation in this investigation.

You must be 20 years of age or older to take part in this research study.

If you agree to take part in this research study and the information outlined above, and to have your body measurements taken, please sign your name and indicate the date below. You will be given a copy of this signed and dated consent form for your records.

__________________ __________________ - _______________________ -

Date Date of Birth Subject's Signature

__________________ ____________________

Date Investigator's Signature

Appendix C

Demographics and Health Questionnaire

Subject Profile

Name ______________________________ Date ____________________

Address ____

____

____

Phone (w): ____________________________ (h): ____________________

Age: ________________ Date of Birth: ________________ Sex: M F

Height: ________________ Weight: ________________

Do you smoke: ☐ Yes ☐ No If yes, how many cigarettes per day? ____________

Ethnicity (*please check only one)*:
☐ HISPANIC OR LATINO
☐ NOT HISPANIC OR LATINO

Race *(please check only one)*:
☐ AMERICAN INDIAN/ALASKAN NATIVE
☐ ASIAN
☐ BLACK OR AFRICAN AMERCIAN
☐ WHITE
☐ HAWAIIAN/PACIFIC ISLANDER

What time do you usually eat the following meals?

Breakfast: ________________ Dinner: ________________
Lunch: ________________ Snack(s): ________________

Are there foods you don't eat because they are not good for you or disagree with you?

☐ Yes ☐ No

If yes, what foods? ________________________________

Are there any foods you don't eat because of medication you are on? ☐ Yes ☐ No

If yes, what foods? ________________________________

Are there any foods you make it a point to eat because you feel they are good for your health?

☐ Yes ☐ No

If yes, what foods? ________________________________

Are there any foods you don't eat because they are difficult to chew? ☐ Yes ☐ No

If yes, what foods? ________________________________

Are you currently under a physician's care? ☐ Yes ☐ No

Do you have, or have you had any of the following?
☐ High blood pressure
☐ Heart trouble
☐ Thyroid or other glandular disorders
☐ Liver disease
☐ Anemia
☐ Cancer
☐ Diabetes
☐ Ulcers (of the digestive system)
☐ Other stomach/intestinal disorder
☐ Kidney disease
☐ Depression
☐ Respiratory illness (asthma, etc.)
☐ Other, please specify ________________________________

Are you presently taking medication (over the counter and/or prescription)? ☐ Yes ☐ No

If yes, please specify: ______________________________

Have you ever received radiation therapy? ☐ Yes ☐ No

Have you ever received chemotherapy? ☐ Yes ☐ No

Please answer the following questions concerning your weight history:

Current weight: ______________________

Highest past adult weight *(excluding pregnancy)*: ______________________

When did this occur? ______________________

Lowest past adult weight: ____________ When did this occur? ____________

Have you experienced any weight change in the last 6 months? ☐ Yes ☐ No

If yes, did you gain or lose? ____________ How much? ____________

When did this weight change occur? ______________________

Do you have any of the following eating related problems? Please check all those that apply:

☐ Sore mouth
☐ Swallowing problems
☐ Chewing problems
☐ Choking problems
☐ Salivation problems
☐ Other, please specify ______________________
☐ Nausea
☐ Vomiting
☐ Diarrhea
☐ Constipation

Are you currently on any kind of special diet? ☐ Yes ☐ No

If yes, what kind (low-salt, low-fat, etc.)? ______________________

What type of exercise do you participate in regularly? ______________________

How many times a week do you exercise? ______________________

How long is each exercise session? ______________________

Do you take any kind of vitamin/mineral supplement? ☐ Yes ☐ No

If yes, what kind do you use and how often do you take them?

____

Please circle the statement that best describes you:

I prefer the meat (poultry, fish, beef) part of a meal	I prefer the vegetable part of a meal	I prefer the starch part of a meal	I have no preference

Below are statements that you will answer about your current eating habits. Please indicate the extent to which you agree with each, using the following scale. (Circle one number for each statement.)

1 – Never **2 – Rarely** **3 – Sometimes** **4 – Often** **5 – Always**

***Current eating habits*:**

I clean my plate:	1	2	3	4	5
I eat my meals about the same time each day:	1	2	3	4	5
I decide how much food is served to me:	1	2	3	4	5

What do you think is the purpose of the research conducted in this lab?

____

____

Females only:

1) In the previous 12 months, has your menstrual cycle been ***(please check only one)***:
   - ☐ Regular (normal cycles of approximately equal length)
   - ☐ Irregular (missed cycles, cycles of varying length, marked changes in flow)
     Please explain ____
   - ☐ I did not menstruate in the last 12 months

2) How many days does your menstrual cycle last (from the beginning of the menstrual period to the beginning of the next period? ________________________________

3) Have you taken any hormones (birth control pills, Depo-Provera®, hormone replacement therapy, etc.) in the past year? ____

4) Have you given birth in the past 12 months? ☐ Yes ☐ No

5) Are you planning to become pregnant within the next 12 months? ☐ Yes ☐ No

6) When was the first day of your last menstrual cycle? ______________________

Appendix D

Zung Questionnaire

Instructions: Please answer the questions by marking an X in the box that best describes your response. If a question does not apply, mark the box that is closest to answering the question.

	None or a little of the time	**Some of the time**	**Good part of the time**	**Most or all of the time**
1. I feel downhearted, blue, and sad				
2. Morning is when I feel the best				
3. I have crying spells, or feel like it				
4. I have trouble sleeping through the night				
5. I eat as much as I used to				
6. I enjoy looking at, talking to, and being with attractive people of the opposite sex				
7. I notice that I am losing weight				
8. I have trouble with constipation				
9. My heart beats faster than usual				
10. I get tired for no reason				
11. My mind is as clear as it used to be				
12. I find it easy to do the things I used to do				
13. I am restless and can't sleep				
14. I feel hopeful about the future				
15. I am more irritable than usual				
16. I find it easy to make decisions				
17. I feel that I am useful and needed				
18. My life is pretty full				
19. I feel that others would be better off if I were dead				
20. I still enjoy the things I used to do				

Appendix E

Eating Attitudes Test Questionnaire

Instructions: Please place an X in the column which applies best to each of the numbered statements. All of the results will be strictly confidential. Please answer each question carefully.	**ALWAYS**	**VERY OFTEN**	**OFTEN**	**SOMETIMES**	**RARELY**	**NEVER**
1. I am terrified about being overweight.						
2. I avoid eating when I am hungry.						
3. I find myself preoccupied with food.						
4. I have gone on eating binges where I feel that I may not be able to stop.						
5. I cut my food into small pieces.						
6. I am aware of the caloric content of foods that I eat.						
7. I particularly avoid foods with a high carbohydrate content (such as bread, potatoes, or rice).						
8. I feel that others would prefer if I ate more.						
9. I vomit after I have eaten.						
10. I feel extremely guilty after eating.						
11. I am preoccupied with a desire to be thinner.						
12. I think about burning up calories when I exercise.						
13. Other people think that I am too thin.						
14. I am preoccupied with the thought of having fat on my body.						
15. I take longer than others to eat my meals.						
16. I avoid foods with sugar in them.						
17. I eat diet foods.						
18. I feel that food controls my life.						
19. I display self-control around food.						
20. I feel that others pressure me to eat.						
21. I give too much time and thought to food.						
22. I feel uncomfortable after eating sweets.						
23. I engage in dieting behavior.						
24. I like my stomach to be empty.						
25. I enjoy trying rich new foods.						
26. I have the impulse to vomit after meals.						

Appendix F

Eating Inventory Questionnaire

Read each of the following 36 statements carefully.
If you agree with the statement, or feel that it is true as applied to you, answer <u>true</u> by circling the "T".
If you disagree with the statement, or feel that it is false as applied to you, answer <u>false</u> by circling the "F".

1.	When I smell a freshly baked pizza, I find it very difficult to keep from eating, even if I have just finished a meal.	T	F	19.	Being with someone who is eating often makes me hungry enough to eat also.	T	F
2.	I usually eat too much at social occasions, like parties and picnics.	T	F	20.	When I feel sad or blue, I often overeat.	T	F
3.	I am usually so hungry that I eat more than three times a day.	T	F	21.	I enjoy eating too much to spoil it by counting calories, counting grams of fat, or watching my weight.	T	F
4.	When I have eaten my quota of calories or fat, I am usually good about not eating any more.	T	F	22.	When I see a real delicacy, I often get so hungry that I have to eat it right away.	T	F
5.	Dieting is so hard for me because I just get too hungry.	T	F	23.	I often stop eating when I am not really full as a conscious means of limiting the amount that I eat.	T	F
6.	I deliberately take small helpings as a means of controlling my weight.	T	F	24.	I get so hungry that my stomach often seems like a bottomless pit.	T	F
7.	Sometimes things just taste so good that I keep on eating even when I am no longer hungry.	T	F	25.	My weight has hardly changed at all in the last ten years.	T	F
8.	Since I am often hungry, I sometimes wish that an expert would tell me that I have had enough to eat or that I can have some more.	T	F	26.	I am always hungry, so it is hard for me to stop eating before I finish the food on my plate.	T	F
9.	When I feel anxious, I find myself eating.	T	F	27.	When I feel lonely, I console myself by eating.	T	F
10.	Life is too short to worry about dieting.	T	F	28.	I consciously hold back at meals in order not to gain weight.	T	F
11.	Since my weight goes up and down, I have gone on reducing diets more than once.	T	F	29.	I sometimes get very hungry late in the evening or at night.	T	F
12.	I often feel so hungry that I just have to eat something.	T	F	30.	I eat anything I want, any time I want.	T	F
13.	When I am with someone who is overeating, I usually overeat too.	T	F	31.	Without even thinking about it, I take a long time to eat.	T	F
14.	I have a pretty good idea of the number of calories or grams of fat in common foods.	T	F	32.	I count calories or grams of fat as a conscious means of controlling my weight.	T	F
15.	Sometimes when I start eating, I just can't seem to stop.	T	F	33.	I do not eat some foods because they make me fat.	T	F
16.	It is not difficult for me to leave something on my plate.	T	F	34.	I am always hungry enough to eat at any time.	T	F
17.	At certain times of the day, I get hungry because I have gotten used to eating then.	T	F	35.	I pay a great deal of attention to changes in my figure.	T	F
18.	While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it.	T	F	36.	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high-calorie foods.	T	F

Please continue on page 2

Each question in this section is followed by a number of options. After reading each question carefully, choose one option which most applies to you, and circle the appropriate answer.

37. How often are you dieting in a conscious effort to control your weight?

1	2	3	4
rarely	sometimes	usually	always

38. Would a weight fluctuation of five pounds affect the way you live your life?

1	2	3	4
not at all	slightly	moderately	very much

39. How often do you feel hungry?

1	2	3	4
only at meal times	sometimes between meals	often between meals	almost always

40. Do your feelings of guilt about overeating help you to control your food intake?

1	2	3	4
never	rarely	often	always

41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?

1	2	3	4
easy	slightly difficult	moderately difficult	very difficult

42. How conscious are you of what you are eating?

1	2	3	4
not at all	slightly	moderately	extremely

43. How frequently do you avoid buying a large amount of tempting foods?

1	2	3	4
almost never	seldom	usually	almost always

44. How likely are you to shop for low-calorie or low-fat foods?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

45. Do you eat sensibly in front of others and splurge alone?

1	2	3	4
never	rarely	often	always

46. How likely are you to consciously eat slowly in order to cut down on how much you eat?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

47. How frequently do you skip dessert because you are no longer hungry?

1	2	3	4
almost never	seldom	at least once a week	almost every day

48. How likely are you to consciously eat less than you want?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

49. Do you go on eating binges even though you are not hungry?

1	2	3	4
never	rarely	sometimes	at least once a week

50. To what extent does this statement describe your eating behavior?

" I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow. "

1	2	3	4
not like me	a little like me	pretty good description of me	describes me perfectly

51. On the following scale of 1 to 6, where 1 means no restraint in eating (eat whatever you want, whenever you want it) and 6 means total restraint (constantly limiting food intake and never "giving in"), what number would you give yourself?

1 Eat whatever you want, whenever you want it

2 Usually eat whatever you want, whenever you want it

3 Often eat whatever you want, whenever you want it

4 Often limit food intake, but often "give in"

5 Usually limit food intake, rarely "give in"

6 Constantly limit food intake, never "give in"

Appendix G

Study Consent Form

(Study 1)

INFORMED CONSENT FORM FOR BIOMEDICAL RESEARCH
The Pennsylvania State University

Title of Project: Perceptions of Different Tastes - 5
IRB# 30120

ORP OFFICE USE ONLY
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IRB# 32887 Doc. # 1002
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 03-19--2010 JDM
Expiration Date: 03-17-2011 JDM

Principal Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
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EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

Other Investigator(s): Jennifer Meengs
226 Henderson Bldg. Penn State University
University Park, PA 16802
814-863-8482

1. Purpose of the study: The purpose of this research is to investigate eating behaviors at different meals.

2. Procedures to be followed: This study will last for 4 weeks. One day each week you will be asked to eat breakfast, lunch and dinner in our lab. At all meals you may eat as little or as much as you would like. On test days, you will only be permitted to eat and drink foods, other than water, that are provided to you by the lab. A variety of snacks will be provided for you to have in the evening, and we ask you return all snack bags, whether eaten or uneaten, to the lab the next day. You may drink water between meals, but we ask that you not drink one hour before a test meal. Throughout the test day you will be asked to rate your hunger, thirst and other sensations. You will also be asked to rate the sensory qualities of food items throughout the sessions. You will be asked to complete a Food and Activity Diary the day before each test session. You will be asked to keep the amount of food eaten at dinner the night before each test session as consistent as possible each week and to refrain from eating or drinking (other than water) after 10:00 p.m. on the evening before each test session. You will also be asked to refrain from drinking alcohol and maintain your usual activity level the day before each test day. Questionnaires at meals will ask if you have consumed any alcohol. If you are a minor and admit to alcohol use, that information will remain confidential. All foods served are commercially available.

You will complete a questionnaire about your general well being during each session. You will also be asked to rate the sensory properties (i.e. taste, texture) of various foods at each meal and to record your hunger, thirst, fullness and nausea during test days. At the end of the study, you will be asked to complete a debriefing questionnaire.

Since each participant can have a great impact on the study, it is important that you carefully adhere to the guidelines of the study. If you feel that this is not possible, please do not join the study.

If during any session you think that some factor may have influenced your behavior or responses, please notify the experimenter immediately. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study.

3. Discomforts and risks: There are no risks involved in eating the test meals and filling out questionnaires. It may be possible that someone could have an allergic reaction to one of the food items or food item ingredients. Allergies will be screened prior to study participation.

4. Benefits: You will be aiding in our understanding of human eating behavior.

5. Duration/Time Commitment: Each test meal will take approximately 20-30 minutes, for no more than 1 ½ hours each test day. The day before each test day it will take up to 15 minutes to record food intake and physical activity.

6. **Statement of confidentiality**: Your participation in this research is confidential. You will be identified by subject number and an assigned dot color. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. The Pennsylvania State University's Office for Research Protections and Institutional Review Board, and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this project.

7. Right to ask questions: Please contact Jennifer Meengs at (814) 863-8481 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact The Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

8. **Compensation** : In addition to test meals, you will be paid $15.00 for completing each day (session) in the lab, consisting of breakfast, lunch, and dinner, for a total of $60 for sessions in the lab; and a $15 bonus for completing all study components, for a possible total of $75.00. Payment will not be made until the completion of the study, unless you withdraw from the study, and then you will be paid for sessions completed.

9. Voluntary participation: Participation is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

10. Injury Clause: In the unlikely event you become injured as a result of your participation in this study, medical care is available but neither financial compensation nor free medical treatment is provided. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators**.**

You must be 20 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent for your records.

____ ______________________

Participant Signature Date

____ ______________________

Signature of Person Obtaining Consent Date

Appendix H

Recipes for Manipulated Entrées

(Study 1)

Oatmeal					
Ingredient	Standard ED	Reduced ED Decrease fat	Reduced ED Increase F&V	Reduced ED Add water	Directions:
Quick oats	170.1 g	181.6 g	117.9 g	135.7 g	Combine oats, brown sugar, & cinnamon in bowl. Add peaches, melted butter, and warmed milk to bowl. Microwave uncovered (times vary according to the condition).
Brown sugar	35.2 g	37.6 g	24.4 g	28.1 g	
Ground cinnamon	4.6 g	3.7 g	3.2 g	3.7 g	
Peaches, canned, drained, chopped	17 g	18.2 g	226.6 g	13.6 g	
Skim milk, warmed	427.7 g	456.7 g	296.4 g	341.2 g	
Whipped butter, melted	45.4 g	1 g	31.5 g	36.2 g	
Water	0 g	0 g	0 g	141.6 g	

Tex-Mex Pasta					
Ingredient	Standard ED	Reduced ED Decrease fat	Reduced ED Increase F&V	Reduced ED Add water	Directions:
Ground beef, 90%, cooked, crumbled	32.2 g	33.8 g	24.8 g	25.8 g	Preheat oven to 325ºF. Combine all ingredients in a large bowl. Put contents of the bowl into a greased casserole dish and bake for 30 minutes.
Onion, chopped	2.4 g	2.5 g	34.7 g	1.9 g	
Chili powder	1.7 g	1.8 g	1.3 g	1.8 g	
Diced tomatoes, canned, chopped	6 g	6.3 g	86.6 g	4.8 g	
Salsa, mild	183 g	191.9 g	141 g	146.5 g	
Tomato sauce	130.8 g	137.2 g	100.8 g	104.7 g	
Rotini pasta, cooked 7 minutes	425.8 g	446.5 g	328.1 g	340.9 g	
Red bell pepper, chopped	7 g	7.3 g	101.3 g	5.6 g	
2% sharp cheddar cheese, finely shredded	83.7 g	87.8 g	64.5 g	67 g	
Olive oil	45.4 g	2.9 g	35 g	36.3 g	
Water	0 g	0 g	0 g	183 g	

Chicken Rice Casserole					
Ingredient	Standard ED	Reduced ED Decrease fat	Reduced ED Increase F&V	Reduced ED Add water	Directions:
Chicken breast, cooked, chopped	76.7 g	80.2 g	58.8 g	61.6 g	Preheat oven to 325ºF. Combine all ingredients in a large bowl. Put contents of the bowl into a greased casserole dish and bake for 45 minutes.
Cream of mushroom soup, 98% fat free, condensed	130.5 g	136.4 g	100 g	104.8 g	
Cream of chicken soup, 98% fat free, condensed	130.5 g	136.4 g	100 g	104.8 g	
Instant rice, dry	183.9 g	192.3 g	140.9 g	147.6 g	
Water	255 g	266.6 g	195.4 g	393.4 g	
Carrots, chopped	14.8 g	15.5 g	34.5 g	11.9 g	
Green peas	14.8 g	15.5 g	30.7 g	11.9 g	
Broccoli florets, chopped	19.8 g	20.7 g	42.1 g	15.9 g	
Cauliflower, puréed	4.8 g	5 g	76.6 g	3.9 g	
Squash, puréed	4 g	4.2 g	84.3 g	3.2 g	
2% sharp cheddar cheese, finely shredded	76.7 g	80.2 g	58.8 g	61.6 g	
Canola oil	44.5 g	3 g	34.1 g	35.7 g	
Ground white pepper	0.3 g	0.3 g	0.3 g	0.2 g	
Onion powder	0.7 g	0.7 g	0.6 g	0.6 g	

Appendix I

Food and Activity Diary

Food and Activity Diary

ID_____________

Date___________ **S M T W**

Please record all foods and beverages that are consumed the day before your session begins. Please remember to not eat anything after 10:00pm and do not eat in a restaurant the night before your session begins. In completing this worksheet, please try to be as accurate as possible and include as much detail as you can (e.g. the brand names of foods, amounts, meal or snack times, beverages). Do not forget to include condiments such as butter, ketchup, mustard, and jelly. If you run out of spaces, please use the back of this form. Also, please leave excess spaces blank. For example, if you have not eaten an appetizer at dinner, please leave that space blank.

If you have any questions about completing this food diary, please call the Food Lab at 863-8482. Thank you for your cooperation.

Breakfast – Foods and beverages (including brand names)

Time: ___________ **Place**: ______________

Foods: ____

____

____

____

Beverages: ____

____

____

Lunch - Foods and beverages (including brand names):

Time: ______________________ **Place:** _____________________

Main Dish: ____

____

Side Dishes (ex. Vegetables, salads, etc.): ____

____

Desserts/sweets: ____

Beverages: ____

____

Dinner - Foods and beverages (including brand names):

Time: ______________________ **Place:** ____

Main Dish: ____

____

Side Dishes (ex. Vegetables, salads, etc.): ____

____

Bread/rolls: ____

Desserts/sweets: ____

Beverages: ____

____

Snacks (all day) -
Snack/Time Consumed: ____

Snack/Time Consumed: ____

Snack/Time Consumed: ____

Physical Activity

Please record all physical activity for the day before your test session. Please remember to keep it as consistent as possible each week. Thank you.

Before breakfast:

____
____
____

Between breakfast and lunch:

____
____
____

Between lunch and dinner:

____
____
____

After dinner:

____
____
____

Appendix J

Meal Reports

Breakfast Report

Subject ID: _________ Date: __________ Week: _________

1. Have you felt well in the last 24 hours?

   ________Yes ________No

   If No, please explain: ____

2. Have you taken any medication in the last 24 hours?

   ________Yes ________No

   If Yes, please list: ____

3. Did you get a good night's sleep last night?

   ________Yes ________No

   If No, please explain: ____

4. Have you maintained your usual level of physical activity the last 24 hours?

   ________Yes ________No

   If No, please explain: ____

5. Have you consumed any foods or caloric beverages since 10 PM last night?

   ________Yes ________No

   If Yes, please indicate what food(s) and approximate amount(s):

____

____

6. Have you consumed alcohol in the past 24 hours?

   _________Yes _________No

   If Yes, what type and how much: ______________________________

____

Lunch Report

Subject ID: __________ Date:____________ Week:_____________

1. Have you felt well since breakfast?

_____ Yes _____No

If No, please explain:

____

2. Have you taken any medication since breakfast?

_____Yes _____No

If Yes, please list:

____

3. Have you consumed any foods or beverages since breakfast, other than water?

_____Yes _____No

If Yes, please indicate what food(s) and approximate amount(s):

____

____

Dinner Report

Subject ID:__________ Date:____________ Week:_____________

1. Have you felt well since lunch?

_____ Yes _____No

If No, please explain:

____

2. Have you taken any medication since lunch?

_____Yes _____No

If Yes, please list:

____

3. Have you consumed any foods or beverages since lunch, other than water?

_____Yes _____No

If Yes, please indicate what food(s) and approximate amount(s):

____

____

Appendix K

Discharge Questionnaire

Discharge Questionnaire

Use the back of this questionnaire if additional space is needed.

1. What do you think the purpose of this study was?

2. Were there any factors that affected how much food you ate? Yes No
   If yes, please explain:

3. Did you notice any differences between any of the sessions? Yes No
   If yes, please explain:

4. Do you have any specific comments about this study? Do you have any comments that may help us with future studies?

Thank you for your participation!!!
Food Lab Staff & Students

Appendix L

Fat Preference Questionnaire

(Study 1)

Food Preference Questionnaire

Instructions: You will be presented with 19 sets of foods. For each set, please:

a. Indicate if you have **ever eaten** the foods by checking either Yes ☑ or No ☑ for each item.

b. Circle the number next to the food that you think **tastes better**, like this: Cake ---- 1

c. Circle the number next to the food that you **eat more often**, like this: Bread ---- 2

Consider your *current* preferences when selecting which foods taste better and which foods you eat more often.

Assume that all foods have not been modified in calories, sugar, or fat, unless it is specifically stated otherwise.

---

1. Chocolate Candy *or* Hard Candy

a. Have you ever eaten: Chocolate candy? Yes ☐ No ☐
Hard candy? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 2.

b. Which food tastes better? (Circle one)
Chocolate candy -------------------------- 1
Hard candy --------------------------------- 2

c. Which food do you eat more often? (Circle one)
Chocolate candy -------------------------- 1
Hard candy --------------------------------- 2
I no longer eat any of these foods ------ 3

---

2. Bagel with Cream Cheese *or* Plain Bagel

a. Have you ever eaten:

Bagel with *regular* cream cheese, butter, or margarine?	Yes ☐	No ☐
Bagel with *reduced-fat* cream cheese, butter, or margarine?	Yes ☐	No ☐
Plain bagel?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 3.

b. Which food tastes better? (Circle one)

Bagel with *regular* cream cheese/butter/margarine ---------	1
Bagel with *reduced-fat* cream cheese/butter/margarine ---	2
Plain bagel --	3

c. Which food do you eat more often? (Circle one)

Bagel with *regular* cream cheese/butter/margarine ---------	1
Bagel with *reduced-fat* cream cheese/butter/margarine ---	2
Plain bagel --	3
I no longer eat any of these foods ------------------------------	4

3. Baked Potatoes *or* French Fries

a. Have you ever eaten:

Baked potato with sour cream or butter?	Yes ☐	No ☐
French fries?	Yes ☐	No ☐
Baked potato with reduced-fat topping?	Yes ☐	No ☐
Plain baked potato?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 4.

b. Which food tastes better? (Circle one)

Baked potato with sour cream or butter --	1
French fries --------------------------------	2
Baked potato with reduced-fat topping --	3
Plain baked potato ------------------------	4

c. Which food do you eat more often? (Circle one)

Baked potato with sour cream or butter --	1
French fries --------------------------------	2
Baked potato with reduced-fat topping --	3
Plain baked potato ------------------------	4
I no longer eat any of these foods -------	5

4. Full-fat Ice Cream *or* Reduced-fat Ice Cream

a. Have you ever eaten: Full-fat ice cream? Yes ☐ No ☐
Reduced-fat ice cream? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 5.

b. Which food tastes better? (Circle one)
Full-fat ice cream -------------------------- 1
Reduced-fat ice cream --------------------- 2

c. Which food do you eat more often? (Circle one)
Full-fat ice cream -------------------------- 1
Reduced-fat ice cream --------------------- 2
I no longer eat any of these foods ------- 3

5. Cream Soups *or* Clear Soups

a. Have you ever eaten: Cream soups? Yes ☐ No ☐
Clear soups? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 6.

b. Which food tastes better? (Circle one)
Cream soups -------------------------------- 1
Clear soups --------------------------------- 2

c. Which food do you eat more often? (Circle one)
Cream soups -------------------------------- 1
Clear soups --------------------------------- 2
I no longer eat any of these foods -------- 3

6. Sautéed/Fried Vegetables *or* Plain Steamed Vegetables

a. Have you ever eaten: Sautéed or fried vegetables? Yes ☐ No ☐
Plain steamed vegetables? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 7.

b. Which food tastes better? (Circle one)
Sautéed or fried vegetables --------------- 1
Plain steamed vegetables ------------------ 2

c. Which food do you eat more often? (Circle one)
Sautéed or fried vegetables --------------- 1
Plain steamed vegetables ------------------ 2
I no longer eat any of these foods -------- 3

---

7. Sandwiches with Mayonnaise *or* Sandwiches without Mayonnaise

a. Have you ever eaten:

Sandwiches with *regular* mayonnaise?	Yes ☐	No ☐
Sandwiches with *reduced-fat* mayonnaise?	Yes ☐	No ☐
Sandwiches *without* mayonnaise?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 8.

b. Which food tastes better? (Circle one)

Sandwiches with *regular* mayonnaise -- 1
Sandwiches with *reduced-fat* mayonnaise -- 2
Sandwiches *without* mayonnaise ----------- 3

c. Which food do you eat more often? (Circle one)

Sandwiches with *regular* mayonnaise ----- 1
Sandwiches with *reduced-fat* mayonnaise - 2
Sandwiches *without* mayonnaise ----------- 3
I no longer eat any of these foods ---------- 4

---

8. Full-fat Cheese *or* Reduced-fat Cheese

a. Have you ever eaten:

Full-fat cheese?	Yes ☐	No ☐
Reduced-fat cheese?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 9.

b. Which food tastes better? (Circle one)

Full-fat cheese -------------------------------- 1
Reduced-fat cheese -------------------------- 2

c. Which food do you eat more often? (Circle one)

Full-fat cheese -------------------------------- 1
Reduced-fat cheese -------------------------- 2
I no longer eat any of these foods ---------- 3

---

9. Pancakes with Butter/Margarine *or* Pancakes without Butter/Margarine

a. Have you ever eaten:

Pancakes with *regular* butter/margarine?	Yes ☐	No ☐
Pancakes with *reduced-fat* margarine?	Yes ☐	No ☐
Pancakes *without* butter/margarine?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 10.

b. Which food tastes better? (Circle one)

Pancakes with *regular* butter/margarine --- 1
Pancakes with *reduced-fat* margarine ------ 2
Pancakes *without* butter/margarine --------- 3

c. Which food do you eat more often? (Circle one)

Pancakes with *regular* butter/margarine --- 1
Pancakes with *reduced-fat* margarine ------ 2
Pancakes *without* butter/margarine --------- 3
I no longer eat any of these foods ---------- 4

---

10. Baked/Broiled/Grilled Fish *or* Fried Fish

a. Have you ever eaten: Baked, broiled or grilled fish? Yes ☐ No ☐
Fried fish? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 11.

b. Which food tastes better? (Circle one)
- Baked, broiled, or grilled fish ------------ 1
- Fried fish ----------------------------------- 2

c. Which food do you eat more often? (Circle one)
- Baked, broiled, or grilled fish ------------ 1
- Fried fish ----------------------------------- 2
- I no longer eat any of these foods -------- 3

11. Hamburger *or* Grilled Chicken Sandwich

a. Have you ever eaten: A hamburger? Yes ☐ No ☐
A grilled chicken sandwich? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 12.

b. Which food tastes better? (Circle one)
- Hamburger --------------------------------- 1
- Grilled chicken sandwich ----------------- 2

c. Which food do you eat more often? (Circle one)
- Hamburger --------------------------------- 1
- Grilled chicken sandwich ----------------- 2
- I no longer eat any of these foods -------- 3

12. Salad with Full-fat Dressing *or* Salad with Reduced-fat Dressing

a. Have you ever eaten: Salad with *full-fat* dressing Yes ☐ No ☐
Salad with *reduced-fat* dressing? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 13.

b. Which food tastes better? (Circle one)
- Salad with *full-fat* dressing --------------- 1
- Salad with *reduced-fat* dressing ---------- 2

c. Which food do you eat more often? (Circle one)
- Salad with *full-fat* dressing --------------- 1
- Salad with *reduced-fat* dressing ---------- 2
- I no longer eat any of these foods -------- 3

13. Pasta with Tomato Sauce *or* Pasta with Cream/Cheese Sauce

a. Have you ever eaten:

Pasta with tomato sauce?	Yes ☐	No ☐
Pasta with cream or cheese sauce?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 14.

b. Which food tastes better? (Circle one)

Pasta with tomato sauce -------------------	1
Pasta with cream or cheese sauce ------	2

c. Which food do you eat more often? (Circle one)

Pasta with tomato sauce -------------------	1
Pasta with cream or cheese sauce ------	2
I no longer eat any of these foods -------	3

14. Regular Cheese Pizza *or* Pizza with Meat (Pepperoni, Sausage, Salami, Bacon) or Extra Cheese

a. Have you ever eaten:

Regular cheese pizza?	Yes ☐	No ☐
Pizza with meat or extra cheese?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 15.

b. Which food tastes better? (Circle one)

Regular cheese pizza ----------------------	1
Pizza with meat or extra cheese ---------	2

c. Which food do you eat more often? (Circle one)

Regular cheese pizza ----------------------	1
Pizza with meat or extra cheese ---------	2
I no longer eat any of these foods -------	3

15. Plain Raw Vegetables *or* Vegetables with Dip

a. Have you ever eaten:

Plain raw vegetables?	Yes ☐	No ☐
Vegetables with *reduced-fat* dip?	Yes ☐	No ☐
Vegetables with *full-fat* dip?	Yes ☐	No ☐

If you answered "No" for all of the items above, please go to Question 16.

b. Which food tastes better? (Circle one)

Plain raw vegetables -----------------------	1
Vegetables with *reduced-fat* dip --------	2
Vegetables with *full-fat* dip --------------	3

c. Which food do you eat more often? (Circle one)

Plain raw vegetables -----------------------	1
Vegetables with *reduced-fat* dip ---------	2
Vegetables with *full-fat* dip --------------	3
I no longer eat any of these foods -------	4

16. Reduced-fat Cookies *or* Full-fat Cookies

a. Have you ever eaten: Reduced-fat cookies? Yes ☐ No ☐
Full-fat cookies? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 17.

b. Which food tastes better? (Circle one)

Reduced-fat cookies ----------------------	1
Full-fat cookies ----------------------------	2

c. Which food do you eat more often? (Circle one)

Reduced-fat cookies ----------------------	1
Full-fat cookies ----------------------------	2
I no longer eat any of these foods -------	3

17. Fried Chicken *or* Grilled/Baked/Broiled Chicken

a. Have you ever eaten: Fried chicken? Yes ☐ No ☐
Grilled, baked, or broiled chicken? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 18.

b. Which food tastes better? (Circle one)

Fried chicken ------------------------------	1
Grilled, baked, or broiled chicken -------	2

c. Which food do you eat more often? (Circle one)

Fried chicken ------------------------------	1
Grilled, baked, or broiled chicken ------	2
I no longer eat any of these foods -------	3

18. Reduced-fat Potato Chips *or* Full-fat Potato Chips

a. Have you ever eaten: Reduced-fat potato chips? Yes ☐ No ☐
Full-fat potato chips? Yes ☐ No ☐
If you answered "No" for all of the items above, please go to Question 19.

b. Which food tastes better? (Circle one)

Reduced-fat potato chips -----------------	1
Full-fat potato chips ----------------------	2

c. Which food do you eat more often? (Circle one)

Reduced-fat potato chips -----------------	1
Full-fat potato chips ----------------------	2
I no longer eat any of these foods -------	3

19. Skim Milk *or* Low-fat Milk *or* Whole Milk

a. Have you ever eaten:

Skim milk?	Yes ☐	No ☐
1% milk?	Yes ☐	No ☐
2% milk?	Yes ☐	No ☐
Whole milk?	Yes ☐	No ☐

If you answered "No" for all of the items above,
you are finished with the questionnaire.

b. Which food tastes better? (Circle one)

Skim milk ----------------------------------	1
1% milk -------------------------------------	2
2% milk -------------------------------------	3
Whole milk ---------------------------------	4

c. Which food do you eat more often? (Circle one)

Skim milk ----------------------------------	1
1% milk -------------------------------------	2
2% milk -------------------------------------	3
Whole milk ---------------------------------	4
I no longer eat any of these foods -------	5

Thank you for your participation.

Appendix M

Visual Analog Scales – Hunger/Fullness

How hungry do you feel <u>right now</u>?

Not at all hungry ____ Extremely hungry

How thirsty do you feel <u>right now</u>?

Not at all thirsty ____ Extremely thirsty

How much food do you think you could eat <u>right now</u>?

Nothing at all ____ A large amount

How nauseated do you feel <u>right now</u>?

Not at all nauseated ____ Extremely nauseated

How full do you feel <u>right now</u>?

Not at all full ____ Extremely full

Appendix N

Visual Analog Scales – Palatability

(Study 1)

Subject Number:

Experiment:
Date:
Run:

Based on what you are eating right now,
how much do you like or dislike this ENTRÉE OVERALL (including taste, aroma, & texture)?

Dislike extremely ______________________________ Like extremely

Based on what you are eating right now,
how pleasant is the TASTE of this entrée?

Not at all pleasant ______________________________ Extremely pleasant

Based on what you are eating right now,
how appropriate is the SALTINESS of this entrée?

Not salty enough ______________________________ Much too salty
just right

Based on what you are eating right now,
how appropriate is the TEXTURE of this entrée?

Much too dry ______________________________ Much too moist
just right

Based on what you are eating right now,
how would you describe the amount of CALORIES in this entrée?

Very low in calories ______________________________ Very high in calories

Based on what you are eating right now,
how would you describe that amount of FAT in this entrée?

Very low in fat ______________________________ Very high in fat

Appendix O

Telephone Screening Questionnaire

(Study 2)

Pre-screening Questionnaire

Date:

Age: ___________ Date of Birth: _____________

Height: _________ Weight: _________________

Do you smoke? No Yes

Are you currently taking any prescription or "over the counter" medications regularly? No Yes
If yes, what? ____

Are you currently dieting to gain or lose weight? No Yes

Are you an athlete in training? No Yes

Do you have any food allergies or intolerances? No Yes

Do you have any sugar/sweetener or sodium restrictions? No Yes

Do you have any food restrictions related to religious practices? No Yes:

Are you a vegetarian? No Yes
If no, are there any meats that you exclude from your diet? ___________

Do you like and are willing to eat:

Yogurt with strawberries, granola, and almonds	Yes	No
Chicken and rice casserole with peas, carrots, and broccoli	Yes	No
Pasta and meat sauce with zucchini, green pepper, and onion	Yes	No

Do you regularly eat 3 meals per day? No Yes
If no, what is your usual daily pattern of meals?

Would you be willing to refrain from eating after 10:00 pm the evening before test sessions? No Yes

Would you be willing to refrain from drinking alcoholic beverages the day before each test session? No Yes

Are you pregnant or breast feeding? No Yes

Where did you hear about the study? ___________________________________

Have you participated in any other studies in our lab? No Yes
If yes, what study and when? ____

Are you eligible to work in the United States: Yes No

Are you a: _____Undergraduate semester standing: __________ major:____________
_____ Graduate major: ______________
_____Penn State Staff
_____State College Resident

If criteria are satisfied, take their name and ask them to come to the lab to fill out questionnaires and to have their weight & height recorded.

Name: _________________ Phone: ________________ Appointment: ___________________

Appendix P

Questionnaire Consent Form

(Study 2)

INFORMED CONESNT FORM FOR BIOMEDICAL RESEARCH
Prescreening Questionnaire

ORP OFFICE USE ONLY
DO NOT REMOVE OR MODIFY
IRB# 30120 Doc. #1
The Pennsylvania State University
Office for Research Protections
Approval Date: 01/21/2009 DWM
Expiration Date: 01/13/2010DWM
Biomedical Institutional Review Board

Title of Investigation: Eating Behaviors

Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
226 Henderson Bldg. Penn State University
University Park, PA 16802
EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

Purpose of today's visit: To determine if you meet the criteria to be a participant in this laboratory's human ingestive behavior studies.

Procedure: It will take you approximately 45 minutes to complete this packet of questionnaires. These questionnaires are to determine whether or not the studies conducted at our laboratory are appropriate for you. You will be weighed and your height measured. Our studies require a considerable amount of preparation and, in order to assure reliable results for the studies, it is very important that participants fulfill all criteria of the studies.

Because of strict subject criteria, it may be determined that we cannot have you participate in the current study. There are a variety of reasons why an individual may not be chosen for a particular study. Often the number of responses from potential participants exceeds the number of individuals needed for the study. If you are not chosen to participate at this time, your information will be kept on file and you may be called later to participate in another study.

Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions are personal and might cause discomfort.

If, as a result of filling in the questionnaires, you feel that you would benefit from psychological assistance, or individual counseling, you may contact:

Psychological Clinic of the Penn State University
314 Moore Building
University Park, PA 16802
Phone: (814) 865-2191

Your responses to the questionnaires will be reviewed by a staff member. If any of the questionnaires indicate that you may benefit from professional treatment (i.e. counseling or physician's care), you will be notified by a staff member via telephone within 3 days of review of your questionnaire packet.

Benefits: If you qualify to become a participant in a study at the Human Ingestive Behavior Laboratory, you will be contributing to our understanding of human eating behavior.

Contact Person: Jennifer Meengs
226 Henderson Building
University Park, PA 16802
814-863-8482

Confidentiality: Your responses on the questionnaires will remain confidential. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, Penn State University's Biomedical Review Board, and Penn State University's Office for Research Protections.
Voluntary Participation: Your participation in the research is voluntary. You do not have to answer any questions you do not wish to answer. Your participation is voluntary and you are free to withdraw your consent and terminate your participation at any time. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

Right to Ask Questions: Please contact Jennifer Meengs at 863-8482 with questions, complaints or concerns about the research. You can also call this number if you feel this study has harmed you. Questions about your rights as a research participant may be directed to Penn State University's Office for Research Protections at (814) 865-1775.

Injury: In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

To the best of your knowledge and belief, you have no physical condition or dietary requirements, such as food allergies or food restrictions, which would increase your risk for participation in this investigation.

You must be 20 years of age or older to take part in this research study.

If you agree to take part in this research study and the information outlined above, and to have your body measurements taken, please sign your name and indicate the date below. You will be given a copy of this signed and dated consent form for your records.

__________________	__________________	_______________________
Date	Date of Birth	Subject's Signature
__________________		______________________
Date		Investigator's Signature

Appendix Q

Study Consent Form

(Study 2)

INFORMED CONSENT FORM FOR BIOMEDICAL RESEARCH
The Pennsylvania State University
Title of Project: Eating Behaviors
IRB# 30120

ORP OFFICE USE ONLY
DO NOT REMOVE OR MODIFY
IRB#30120 Doc. #2
The Pennsylvania State University
Office for Research Protections
Approval Date: 01/21/2009 DWM
Expiration Date: 01/13/2010DWM
Biomedical Institutional Review Board

Principal Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
226 Henderson Bldg. Penn State University
University Park, PA 16802
EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

Other Investigator(s): Jennifer Meengs
226 Henderson Bldg. Penn State University
University Park, PA 16802
814-863-8482

1. Purpose of the study: The purpose of this research is to investigate eating behaviors at different meals.

2. Procedures to be followed: This study will last for 5 weeks. One day each week you will be asked to eat breakfast, lunch and dinner in our lab. The first week of the study you will also be asked to wear a pedometer for 3 days and record your daily number of steps and complete a brief activity questionnaire. You will be required to consume a portion of each meal, but may eat as little or as much as you would like of other foods served with the meal. On test days, you will only be permitted to eat and drink foods that are provided to you by the lab until after the dinner meal. After the dinner meal you will be asked to record your evening snack intake and return it the next day. You may drink the water provided to you between meals, but we ask that you not drink one hour before a test meal. Throughout the test day you will be asked to rate your hunger, thirst and other sensations. You will also be asked to rate the sensory qualities of food items throughout the sessions. You will be asked to complete a Food and Activity Diary the day before each test session. You will be asked to keep the amount of food eaten at dinner the night before each test session as consistent as possible each week and to refrain from eating or drinking (other than water) after 10:00 p.m. on the evening before each test session. You will also be asked to refrain from drinking alcohol and maintain your usual activity level the day before each test day. Questionnaires at meals will ask if you have consumed any alcohol. If you are a minor and admit to alcohol use, that information will remain confidential. All foods served are commercially available.

You will complete a questionnaire about your general well being during each session. You will also be asked to rate the sensory properties (i.e. taste, texture) of various foods at each meal and to record your hunger, thirst, fullness and nausea during test days. At the end of the study, you will be asked to complete a debriefing questionnaire.

Since each participant can have a great impact on the study, it is important that you carefully adhere to the guidelines of the study. If you feel that this is not possible, please do not join the study.

If during any session you think that some factor may have influenced your behavior or responses, please notify the experimenter immediately. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study.

3. Discomforts and risks: There are no risks involved in eating the test meals and filling out questionnaires. It may be possible that someone could have an allergic reaction to one of the food items or food item ingredients. Allergies will be screened prior to study participation.

4. Benefits: You will be aiding in our understanding of human eating behavior.

5. Duration/Time Commitment: It will take approximately 1-2 minutes to record daily pedometer steps and 1-2 minutes to complete the activity questionnaire. Each test meal will take approximately 20-30 minutes, for no more than 1 ½ hours each test day. Every test day it will take approximately 1-2 minutes to complete each questionnaire, and 2-3 minutes to record evening snack intake. The day before each test day it will take up to 15 minutes to record food intake and physical activity.

6. **Statement of confidentiality**: Your participation in this research is confidential. You will be identified by subject number and an assigned dot color. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, Penn State University's Biomedical Review Board, and Penn State University's Office for Research Protections.

7. Right to ask questions: You can ask questions about this research. Contact Jennifer Meengs at 863-8482 with questions. You can also call this number if you feel this study has harmed you. If you have questions about your rights as a research participant, contact The Pennsylvania State University's Office for Research Protections at (814) 865-1775.

8. **Compensation** : In addition to test meals, you will be paid $5.00 for recording pedometer steps; $10.00 for completing each day (session) in the lab, consisting of breakfast, lunch, and dinner, for a total of $50 for sessions in the lab; and a $45 bonus for completing all study components, for a possible total of $100.00. Payment will not be made until the completion of the study, unless you withdraw from the study, and then you will be paid for sessions completed.

9. Voluntary participation: Participation is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

10. Injury Clause: In the unlikely event you become injured as a result of your participation in this study, medical care is available but neither financial compensation nor free medical treatment is provided. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators**.**

You must be 20 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent for your records.

____ _____________________

Participant Signature Date

____ _____________________

Signature of Person Obtaining Consent Date

Appendix R

Recipes for Manipulated Entrées

(Study 2)

Yogurt Parfait (recipe for standard energy content entrées for men)			
Ingredient	Standard ED	Reduced ED	Directions:
Plain yogurt	73 g	144 g	Mix yogurt, strawberries, non-caloric sweetener. Immediately before serving mix in almost all of the granola and almonds, leaving some to sprinkle on top.
Plain non-fat yogurt	114 g	101 g	
Strawberries, frozen, chopped	10 g	123 g	
Granola bar, finely chopped	72 g	2 g	
Almonds, finely ground	3 g	53 g	
Non-caloric sweetener	--	3 g	
Chicken Rice Casserole (recipe for standard energy content entrées for men)			
Ingredient	Standard ED	Reduced ED	Directions:
Chicken, cooked, chopped	34.7 g	20 g	Preheat oven to 350ºF. Combine all ingredients in a large bowl. Put into greased casserole dish and bake for 40 minutes.
Cream of chicken soup, condensed	132.3 g	146 g	
Tap water	87.2 g	100.8 g	
Green peas, frozen	10.5 g	74.6 g	
Carrots, frozen, chopped	10.5 g	74.6 g	
Canola oil	10.5 g	8.9 g	
Rice, white, uncooked	90.3 g	67.2 g	
Broccoli florets, frozen	7.4 g	101.9 g	
Pasta Bake (recipe for standard energy content entrées for men)			
Ingredient	Standard ED	Reduced ED	Directions:
Lean beef, cooked	13.7 g	13.7 g	Preheat oven to 350ºF. Combine all ingredients in a large bowl. Put into greased casserole dish and bake for 20 minutes.
Parmesan cheese, grated	8.4 g	7.4 g	
Mozzarella cheese, part-skim, shredded	8.4 g	7.4 g	
Onions, chopped, frozen	5.3 g	33.6 g	
Squash, frozen, chopped	5.3 g	87.2 g	
Green pepper, chopped	6.3 g	104 g	
Marinara sauce	149.1 g	192.2 g	
Olive oil	5.8 g	4.7 g	
Ditalini pasta, cooked	156.5 g	136.5 g	
Bread crumbs, Italian style	18.9 g	11.6 g	

Appendix S

Visual Analog Scales - Palatability

(Study 2)

How pleasant is the appearance of this food <u>right now</u>?

Not at all pleasant ______________________________ Extremely pleasant

How pleasant is the taste of this food <u>right now</u>?

Not at all pleasant ______________________________ Extremely pleasant

How pleasant is the texture of this food <u>right now</u>?

Not at all pleasant ______________________________ Extremely pleasant

How many calories do you think this food has?

No calories at all ______________________________ Extremely high in calories

Appendix T

Telephone Screening Questionnaire

(Study 3)

Pre-screening Questionnaire

Date:
Age: ___________ Date of Birth: _____________
Height: _________ Weight: _________________

Do you smoke? No Yes

Are you currently taking any prescription or "over the counter" medications regularly? No Yes
If yes, what? ____

Are you currently dieting to gain or lose weight? No Yes

Are you an athlete in training? No Yes

Do you have any food allergies or intolerances? No Yes

Do you have any sugar/sweetener or sodium restrictions? No Yes

Do you have any food restrictions related to religious practices? No Yes:

Are you a vegetarian? No Yes If no, are there any meats that you exclude from your diet? ___________

Do you ever have a first course of either soup or salad before your main entrée? Yes No

Do you like and are willing to eat:

A tossed salad with assorted greens, cherry tomato, cucumber, carrots, and Italian dressing	Yes	No
Pasta with cheese and red sauce	Yes	No

Do you regularly eat 3 meals per day? No Yes
If no, what is your usual daily pattern of meals?

Would you be willing to refrain from eating after 10:00 pm the evening before test sessions? No Yes

Would you be willing to refrain from drinking alcoholic beverages the day before each test session? No Yes

Are you pregnant or breast feeding? No Yes

Where did you hear about the study? ___________________________________

Have you participated in any other studies in our lab? No Yes
If yes, what study and when? ____

Are you eligible to work in the United States: Yes No

Are you a: _____Undergraduate semester standing: __________ major:_____________
_____ Graduate major: ______________
_____Penn State Staff
_____State College Resident

If criteria are satisfied, take their name and ask them to come to the lab to fill out questionnaires and to have their weight & height recorded.

Name: _________________ Phone: ________________ Appointment: ___________________

Appendix U

Questionnaire Consent Form

(Study 3)

Informed Consent Form for Biomedical Research
The Pennsylvania State University – Prescreening Questionnaire

ORP OFFICE USE ONLY:
DO NOT REMOVE OR MODIFY
IRB#33923 Doc. #1001
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 05/19/2010 – DWM
Expiration Date: 05/13/2011 – DWM

Title of Investigation: The Effects of a Lunchtime Meal

Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
226 Henderson Bldg., University Park, PA 16802
EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

Purpose of today's visit: To determine if you meet the criteria to be a participant in this laboratory's human ingestive behavior research.

Procedure: It will take you approximately 45 minutes to complete this packet of questionnaires, taste samples of food and have your height and weight measured. These questionnaires are to determine whether or not the studies conducted at our laboratory are appropriate for you. You will be weighed and your height measured. You will also be asked to rate the tastes of different foods. Our studies require a considerable amount of preparation and, in order to assure reliable results for the studies, it is very important that participants fulfill all criteria of the studies.

Because of strict subject criteria, it may be determined that we cannot have you participate in the current study. There are a variety of reasons why an individual may not be chosen for a particular study. Often the number of responses from potential participants exceeds the number of individuals needed for the study. If you are not chosen to participate at this time, your information will be kept on file and you may be called later to participate in another study.

Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions are personal and might cause discomfort.

If, as a result of filling in the questionnaires, you feel that you would benefit from psychological assistance, or individual counseling, you may contact:

Psychological Clinic of the Penn State University
314 Moore Building
University Park, PA 16802
Phone: (814) 865-2191

Your responses to the questionnaires will be reviewed by a staff member. If any of the questionnaires indicate that you may benefit from professional treatment (i.e. counseling or physician's care), you will be notified by a staff member via telephone within 3 days of review of your questionnaire packet.

Benefits: If you qualify to become a participant in a study at the Human Ingestive Behavior Laboratory, you will be contributing to our understanding of human eating behavior.

Contact Person: Jennifer Meengs
226 Henderson Building
University Park, PA 16802
814-863-8482

Confidentiality: Your responses on the questionnaires will remain confidential. The Pennsylvania State University's Office for Research Protections and Institutional Review Board, and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this project.

Voluntary Participation: Your participation in the research is voluntary. You do not have to answer any questions you do not wish to answer. Your participation is voluntary and you are free to withdraw your consent and terminate your participation at any time. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

Right to Ask Questions: Please contact Jennifer Meengs at 863-8482 with questions, complaints or concerns about the research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact the Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

Injury: In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

Please inform the researcher of any dietary requirements, food allergies, or food restrictions, either verbally or on the consent form prior to signing and dating the consent form.

You must be 20 years of age or older to take part in this research study.

If you agree to take part in this research study and the information outlined above, and to have your body measurements taken, please sign your name and indicate the date below. You will be given a copy of this signed and dated consent form for your records.

__________________ __________________ _______________________

Date Date of Birth Subject's Signature

__________________ _______________________

Date Investigator's Signature

Appendix V

Study Consent Form

(Study 3)

Informed Consent Form for Biomedical Research
The Pennsylvania State University

ORP OFFICE USE ONLY:
DO NOT REMOVE OR MODIFY
IRB#33923 Doc. #1002
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 05/13/2011 – J. Mathieu
Expiration Date: 05/09/2012 – J. Mathieu

Title of Project: The Effects of a Lunchtime Meal

Principal Investigator: Barbara Rolls, Ph.D.
Department of Nutrition
226 Henderson Bldg., University Park, PA 16802
EMAIL: bjr4@psu.edu
TELEPHONE: 814-863-8481

Other Investigator(s): Jennifer Meengs
226 Henderson Bldg., University Park, PA 16802
814-863-8482

1. Purpose of the study: The purpose of this research is to investigate eating behaviors at different meals.

2. Procedures to be followed: This study will last for 6 weeks. One day each week you will be asked to eat breakfast and lunch in our lab. At breakfast you may eat as little or as much as you would like. At lunch, you may be served a first course that you are required to consume in full. At all lunches you will be served an entrée that you may eat as little or as much as you would like. On test days, you will only be permitted to eat and drink foods, other than water, that are provided to you by the lab, until after the lunchtime meal. You may drink water between breakfast and lunch, but we ask that you not drink water one hour before the lunch meal. Throughout the test meals you will be asked to rate your hunger, thirst and other sensations. You will also be asked to rate the sensory qualities of food items throughout the sessions. You will be asked to complete a Food and Activity Diary the day before each test session. You will be asked to keep the amount of food eaten at dinner the night before each test session as consistent as possible each week and to refrain from eating or drinking (other than water) after 10:00 p.m. on the evening before each test session. You will also be asked to refrain from drinking alcohol and maintain your usual activity level the day before each test day. Questionnaires at meals will ask if you have consumed any alcohol. If you are a minor and admit to alcohol use, that information will remain confidential. All foods served are commercially available.

You will complete a questionnaire about your general well being during each session. You will also be asked to rate the sensory properties (i.e. taste, texture) of various foods at each meal and to record your hunger, thirst, fullness and nausea during test days. At the end of the study, you will be asked to complete debriefing questionnaires.

Since each participant can have a great impact on the study, it is important that you carefully adhere to the guidelines of the study. If you feel that this is not possible, please do not join the study.

If during any session you think that some factor may have influenced your behavior or responses, please notify the experimenter immediately. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study.

3. Discomforts and risks: There are no risks involved in eating the test meals and filling out questionnaires. It may be possible that someone could have an allergic reaction to one of the food items or food item ingredients. Allergies will be screened prior to study participation.

4. Benefits: You will be aiding in our understanding of human eating behavior.

5. Duration/Time Commitment: Each breakfast meal will take approximately 20 minutes, each lunch approximately 40 minutes, for roughly one hour each test day. It will take approximately 5 minutes to complete the Food and Activity Diary.
6. **Statement of confidentiality**: Your participation in this research is confidential. You will be identified by subject number and an assigned dot color. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. The Pennsylvania State University's Office for Research Protections and Institutional Review Board, and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this project.

7. Right to ask questions: Please contact Jennifer Meengs at (814) 863-8481 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact The Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

8. **Compensation:** In addition to test meals, you will be paid $5.00 for completing each day (session) in the lab, consisting of breakfast and lunch, for a total of $30 for sessions in the lab; and a $20 bonus for completing all study components, for a possible total of $50.00. Payment will not be made until the completion of the study, unless you withdraw from the study, and then you will be paid for sessions completed.

9. Voluntary participation: Participation is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Since we have specific requirements for participants in this study, we reserve the right to reschedule or drop you from the study at any time. If that happens, you will be compensated for any time that you have already given to the study. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

10. Injury Clause: In the unlikely event you become injured as a result of your participation in this study, medical care is available but neither financial compensation nor free medical treatment is provided. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators**.**

You must be 20 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent for your records.

____ ____________________

Participant Signature Date

____ ____________________

Signature of Person Obtaining Consent Date

Appendix W

Recipe for Unmanipulated Salad Preload

(Study 3)

Salad preload		
Ingredient	Amount	Directions:
Fat Free Italian dressing Mixed greens Romaine lettuce, shredded Cucumber, peeled, seeded, chopped Parmesan cheese, grated Cherry tomatoes, halved Carrots, grated Iceberg lettuce, shredded	52 g 20 g 45 g 46 g 7 g 60 g 30 g 40 g	Combine mixed greens, romaine lettuce, cucumber, cherry tomato, carrots, & iceberg lettuce in a large bowl. Combine Italian dressing and parmesan cheese in a small bowl. Add mixture from the small bowl to the large bowl and toss. Put contents into a bowl for serving.

Appendix X

Recipes for Manipulated Entrées

(Study 3)

Pasta bake			
Ingredient	Standard ED	Increased ED	Directions:
Elbow pasta, cooked 6 minutes	700 g	700 g	Preheat oven to 325ºF. Combine all ingredients in a large bowl. Put contents of the bowl into a greased casserole dish and bake for 30 minutes.
Heavy whipping cream	50 g	50 g	
Parmesan cheese, grated	75 g	75 g	
Whole milk, low-moisture, mozzarella cheese	330 g	330 g	
Traditional pasta sauce	1050 g	1050 g	
Broccoli, puréed	325 g	25 g	
Cauliflower, puréed	325 g	25 g	
Tomato sauce, canned	350 g	25 g	

Appendix Y

Visual Analog Scales - Palatability

(Study 3)

How pleasant is the appearance of this food <u>right now</u>?

Not at all pleasant	______________________________	Extremely pleasant

How pleasant is the taste of this food <u>right now</u>?

Not at all pleasant	______________________________	Extremely pleasant

How pleasant is the texture of this food <u>right now</u>?

Not at all pleasant	______________________________	Extremely pleasant

How filling do you think this serving of food will be?

Not filling at all	______________________________	Extremely filling

How does the size of this serving compare to your usual portion?

A lot smaller	______________________________	A lot larger

How much of this food do you think you could consume <u>right now</u>?

Nothing at all	______________________________	A large amount

How many calories do you think this serving of food has?

No calories at all	______________________________	Extremely high in calories

Curriculum Vitae

Rachel A. Williams

EDUCATION

2013 Ph.D. in Nutritional Sciences, **The Pennsylvania State University**, University Park, PA
2005 B.S. in Nutrition, minor in Education, University Honors Program, **LaSalle University**, Philadelphia, PA

PROFESSIONAL EXPERIENCE

2008-2013 **Doctoral student**, The Pennsylvania State University, University Park, PA
2006-2008 **Clinical Research Coordinator**, Department of Gastroenterology, Hepatology, and Nutrition, The Children's Hospital of Philadelphia, Philadelphia, PA
2005-2005 **Dietetic Intern**, St. Louis Veterans Affairs Medical Center, St. Louis, MO
2004-2005 **Student Nutritionist**, Lehigh Women, Infants, and Children (WIC) Office, Philadelphia, PA
2003 **ORISE Student Researcher**, United States Army Medical Research Institute for Chemical Defense, Aberdeen Proving Ground, MD

AWARDS AND HONORS

2012 Pat Simons Travel Award, The Obesity Society
2012 1st place poster, Penn State Institute for Diabetes and Obesity Research Forum

PUBLICATIONS

Williams RA, Roe LS, Rolls BJ. Assessment of satiety depends on the energy density and portion size of the test meal. *Submitted*.

Williams RA, Roe LS, Rolls BJ. Comparison of three methods to reduce energy density: effects on daily energy intake. *Appetite* 2013;66:75-83.

Blatt AD, **Williams RA**, Roe LS, Rolls BJ. Effects of energy content and energy density of pre-portioned entrées on energy intake. *Obesity* 2012;20:2010-8.

PRESENTATIONS

Oral presentations:

Williams RA, Roe LS, Rolls BJ. Comparing three ways to reduce energy density: does daily energy intake differ? The Obesity Society, September 2012.

Williams RA, Roe LS, Rolls BJ. High-satiety foods: how robust are their effects in an obesogenic environment? The Obesity Society, September 2012.

Williams RA, Blatt AD, Roe LS, Rolls BJ. Effects of energy density and energy content of a pre-portioned entrée on energy intake. Experimental Biology, April 2011.

Poster presentations:

Williams RA, Blatt AD, Roe LS, Rolls BJ. Pre-portioned entrées: do variations in energy density and energy content affect intake? The Obesity Society, October 2011.

Williams RA, Roe LS, Rolls BJ. High-satiety foods: how robust are their effects in an obesogenic environment? The Obesity Society, November 2012.