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The effect of fruit in different forms on energy intake and satiety at a meal

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Abstract

Consuming whole fruit reduces ratings of satiety more than fruit juice, but little is known about the effects of different forms of fruit on subsequent energy intake. This study tested how consuming preloads of apples in different forms prior to a meal (apple, applesauce, and apple juice with and without added fiber) influences satiety and energy intake at meal. Preloads were matched for weight, energy content, energy density, and ingestion rate. Once a week for 5 weeks, 58 adults consumed one of four preloads (266 g; 125 kcal [523 kJ]), or no preload (control), followed by a test meal consumed *ad libitum* 15 min later. Results showed that eating apple reduced lunch energy intake (preload + test meal) by 15% (187 ± 36 kcal [782 ± 151 kJ]) compared to control ($p < 0.0001$) and decreased energy intake compared to applesauce and both juices. Fullness ratings differed significantly after preload consumption (apple > applesauce > both juices > control). Overall, whole apple increased satiety more than applesauce or apple juice. Adding naturally occurring levels of fiber to juice did not enhance satiety. These results suggest that solid fruit affects satiety more than pureed fruit or juice, and that eating fruit at the start of a meal can reduce energy intake.

Keywords

Fruit; Juice; Energy intake; Satiety; Form of food; Energy density

Introduction

Identifying strategies to reduce energy intake and enhance satiety at meals is important for effective weight management. One strategy that may affect energy intake is changing the form in which food is consumed (solid, pureed, or liquid). While the literature on this topic is inconclusive (Bolton, Heaton, & Burroughs, 1981; DiMeglio & Mattes, 2000; Haber, Heaton, Murphy, & Burroughs, 1977; Kissileff, Gruss, Thornton, & Jordan, 1984; Rolls, Fedoroff, Guthrie, & Laster, 1990), several studies have suggested that solid foods have a greater effect on satiety than liquids consumed as beverages (Bolton et al., 1981; DiMeglio & Mattes, 2000; Haber et al., 1977). Fruit is particularly useful for investigating the effects of food form on satiety, because it is frequently consumed as part of a meal, and is readily available in different forms (solid, pureed, and juice).

A few studies have found that consuming fruit (apples, oranges, and grapes) leads to a greater reduction in hunger ratings than consuming the same amount of fruit juice (Bolton et al., 1981; Haber et al., 1977; Mattes, 2005). In these studies, satiety was assessed using rating scales; in one case, subsequent intake was also assessed by food diaries (Mattes, 2005). Thus,

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there is little data on how differences in satiety ratings due to the form of fruit affect energy intake at a meal. In addition, previous studies matched the foods on some of the parameters that could influence satiety, such as weight (Bolton et al., 1981; Haber et al., 1977) or energy content (Mattes, 2005), but not on other variables that have been shown to affect satiety, such as energy density (Rolls, Roe, & Meengs, 2004) and fiber content (Burton-Freeman, 2000; Howarth, Saltzman, & Roberts, 2001). Therefore, one aim of the present study was to expand upon the findings of these previous studies in order to determine whether food served in different forms affects satiety and energy intake independent of variations in energy density or fiber content.

Another aim of this study was to determine whether consumption of fruit, which is low in energy density, affects satiety and energy intake at a meal. Previous research has demonstrated that satiety is enhanced by eating low-energy-dense foods such as soup or salad at the start of a meal (Flood & Rolls, 2007; Rolls, Roe, et al., 2004). Thus, in this study we tested the effect on satiety and meal energy intake of consuming low-energy-dense fruit preloads that were matched for energy content, weight, energy density, and fiber content. The preloads included apple (peeled segments), applesauce, apple juice, and apple juice with added fiber. To separate the effect of food form from that of fiber content, we tested both apple juice with added pectin (to match the level of fiber in the apple and applesauce) and juice without pectin (to match the commercially available product).

Methods

Subjects

Subjects for this study were recruited from a university community by informational flyers, electronic mailing lists, and newspaper advertisements. Individuals who responded to the advertisements were interviewed by telephone to ensure that they met the following criteria: 18–45 years of age, not taking medications that are known to affect appetite or food intake, non-smokers, regularly consume three meals a day, not dieting to gain or lose weight, not athletes in training, and free from food allergies and food restrictions. Only subjects who reported liking apples, applesauce, and apple juice, and who were willing to consume these foods and drinks, were eligible.

Potential subjects who met these initial criteria came to the laboratory to complete additional materials. Included in these materials were the Zung Questionnaire (Zung, 1986), which measures symptoms of depression; the 26-item version of the Eating Attitudes Test (Garner, Olsted, Bohr, & Garfinkel, 1982), which assesses attitudes towards food and eating, and the Eating Inventory (Stunkard & Messick, 1985), which evaluates dietary restraint, disinhibition, and perceived hunger. The Zung Questionnaire and the Eating Attitudes Test were included as screening tools to ensure that subjects did not exhibit symptoms of depression or disordered eating that might influence food intake and study outcomes. Potential subjects who scored <42 on the Zung Questionnaire, and scored <20 on the Eating Attitudes Test were eligible for participation in the study. Scores generated by the Eating Inventory were tested as covariates in the analysis of study outcomes.

Also at this time, trained laboratory personnel took height and weight measurements (model 707; Seca Corp., Hanover, MD, USA), and individuals who had a body mass index of 18–40 kg/m² were eligible to participate. Subjects were told that the purpose of the study was to examine the effects of consumption of various foods and beverages. Subjects gave signed consent and were financially compensated for participation in the study. The study was approved by the Pennsylvania State University Office for Research Protections.

Experimental design

This study used a cross-over design with repeated measures. Subjects came to the laboratory once a week for 5 weeks, for a total of five test sessions consisting of breakfast and lunch. On each test day, a standard breakfast of bagels and yogurt was consumed *ad libitum* in order to ensure a consistent level of hunger before lunch sessions. Lunch was scheduled at least 3 h after breakfast. At the beginning of each lunch meal, subjects were served one of four preloads or no preload. The condition in which no preload was served was considered to be subjects' control intake. Preload ingestion rate was controlled by requiring subjects to pace consumption of the preload over the course of 10 min; when no preload was served, subjects were asked to sit and read quietly for 10 min. The test meal was served 15 min after the preload was served. This time frame was chosen to approximate a meal setting in which a first course (the preload) is consumed prior to a main course (the test meal). At each session, the same test meal was served and subjects could eat or drink as much or as little as they wanted. The order of experimental conditions was randomized across subjects and there were no significant differences in the distribution of conditions across study sessions.

The sample size to be enrolled in this study was based on previous research with a similar subject population and test meal (Flood & Rolls, 2007; Rolls, Roe, et al., 2004; Rolls, Ello-Martin, & Tohill, 2004). According to a power analysis, a sample size of 51 subjects would allow the detection of a 50-kcal [209 kJ] difference in meal energy intake at a significance level of 0.05 and a power of 80%. This represents about 5–7% of typical lunch energy intakes in our laboratory, which was considered to be a clinically significant change.

Foods and beverages

All preloads were derived from apples and were matched for weight (266 g) and energy content (~125 kcal), but each differed in form. For comparison, a large peeled apple typically weighs 216 g (U.S. Department of Agriculture, 2007). The properties of the preloads are shown in Table 1. The apple preload was prepared from apples with the skin removed, which were cut into segments and served on a plate. The applesauce preload was prepared from the same batch of apples used in the apple condition, and was eaten from a bowl with a spoon. In order to make the applesauce, apples were peeled and baked in a covered dish for 45 min at 177 °C. The apples were weighed before and after baking to measure the amount of water that was lost during baking, and water was then added to the apples to account for any water loss that occurred. The apples were then pureed to produce applesauce. All apples used in the apple and applesauce conditions were from the same farm, and were picked during the autumn of 2006 (Ida Red apples; Way Fruit Farm, Port Matilda, PA, USA).

The apple juice preload was commercially made from freshly pressed apples and contained no added sugar and no measurable fiber (Mott's Natural Apple Juice, Rye Brook, NY, USA). The apple juice with fiber preload consisted of the same type of apple juice combined with a low-viscosity, apple-derived pectin supplement (100% apple pectin, Herbstreith & Fox, Elmsford, NY, USA). Both juice preloads were served in a clear plastic glass. The soluble fiber found in the pectin supplement differs from the insoluble fiber found in apple skin. Since different types of fiber could affect satiety differently, the apple and applesauce preloads were prepared and served without the skin. Therefore, both the amount and type of fiber (soluble) were similar in the apple, applesauce, and apple juice with fiber preloads.

The volume of the apple preload was measured by water displacement in a 500-ml beaker, and the volume of the applesauce and juice preloads was measured in a graduated cylinder. Because of the intact cellular structure of the apple, the volume of the apple segments (325 ml) was greater than the volume of the applesauce (258 ml) and apple juice (254 ml). All preloads were served at a temperature of 36 °F.

The test meal consisted of cheese tortellini (612 g; Ralzoni and Bros., Dover, NJ, USA) and tomato sauce (280 g; Traditional Prego, Campbell Soup Co., Camden, NJ, USA), and was accompanied by a liter of drinking water served at 2 °C. The test meal contained 64% of energy from carbohydrate, 16% energy from fat, and 20% of energy from protein, and had an energy density of 2.2 kcal/g [9.2 kJ/g]. All foods and beverages served in the study were commercially available. Portion sizes were based on lunch intake data from previous studies in our laboratory, and provided more energy than most subjects were likely to consume (Flood & Rolls, 2007; Flood, Rolls, & Roe, 2006; Rolls, Roe, et al., 2004; Rolls, Ello-Martin, et al., 2004).

All foods and beverages were weighed prior to being served to subjects, and were re-weighed after the subjects had finished eating to determine the amount of food and beverage consumed by each subject to the nearest 0.1 g. Energy intakes at each meal were calculated using nutrition information from standard food composition tables (U.S. Department of Agriculture, 2007) and provided by the food manufacturers.

Procedures

On test days, subjects were instructed to consume only foods and beverages provided by the laboratory from the time they woke up in the morning until after the lunch session. Subjects were permitted to consume water between meals until 1 h before each test session. Subjects were instructed not to drink alcohol in the 24 h prior to coming to the laboratory, and not to consume dinner in a restaurant the evening before the test session. Subjects were also told to keep the amount of food eaten and physical activity performed the day before coming to the laboratory as consistent as possible across sessions. They completed a food and activity diary the day before each test session to encourage compliance with this protocol.

On test days, subjects came to the laboratory at their assigned meal times and were seated in individual cubicles. Before each meal, they completed a report to evaluate their compliance with the study protocol and to ensure that they were feeling well. At the lunch meal, after the report was completed, the preload was served and subjects were instructed to take 10 min to consume the food or beverage, using a timer to pace themselves. When subjects received no preload, they were given a magazine and asked to sit quietly and read for 10 min. Following the 10-min preload period, they were given 5 min to rate their hunger and satiety and characteristics of the preload. Then, after a total of 15 min, the test meal was served. Subjects were instructed to eat and drink as much or as little of the test meal and water as they wanted. The amount of time taken to consume the test meal was recorded for each subject.

Ratings of hunger, satiety, and food characteristics

During each test session, subjects completed a series of 100-mm visual analog scales (Hetherington & Rolls, 1987) to rate their hunger, thirst, and satiety as assessed by fullness. For example, they answered the question “How full do you feel right now?” by marking the 100-mm line anchored by “Not at all full” on the left side, and “Extremely full” on the right. Subjects completed these ratings before and after breakfast, before and after the preload time period, and after lunch.

Subjects also used 100-mm visual analog scales at each test session to rate characteristics of each preload prior to consumption. They were instructed to take a bite or sip of the preload and rate the pleasantness of the taste. They then rated perceived calorie content and how filling they thought the preload would be. For example, subjects recorded their answer to the question “How pleasant is the taste of this food right now?” by marking a 100-mm line anchored on the left side by “Not at all pleasant” and anchored on the right side by “Extremely pleasant.”

Statistical analysis

A mixed linear model with repeated measures was used to analyze the main outcomes of energy intake (kcal), food intake (g), ratings of hunger, fullness, and thirst, and ratings of preload characteristics (SAS System for Windows, version 9.1; SAS Institute, Cary, NC, USA). The fixed factor effects in the model were preload type and subject sex. When pairwise comparisons of means were made between preload conditions, the overall error rate was controlled using the SIMULATE adjustment in the SAS mixed model; comparisons to the control condition were made using the Dunnett–Hsu adjustment. Intake criteria were established such that any subject who consumed <100 kcal [418 kJ] at one or more lunch sessions would be excluded from analysis. Analysis of covariance was performed to determine whether any subject characteristics (continuous variables including height, weight, BMI, and scores for restraint, disinhibition, hunger, and depression) affected the relationship between preload type and the main outcomes, and to examine the relationship between intake and ratings of hunger and satiety. For each subject, energy intake in each condition was expressed as a percent of the energy consumed in the control condition as follows: total energy intake at lunch (preload + test meal) was divided by total energy intake at lunch in the control condition and multiplied by 100%. All results were considered significant at $p < 0.05$ and are reported as mean \pm standard error.

Results

Subjects

Thirty men and twenty-nine women were enrolled in the study. However, based on the criteria established for minimum lunch intake, one woman was excluded from the analysis. Therefore, the final sample consisted of 30 men and 28 women; the characteristics of these subjects are shown in Table 2.

Food and energy intake

Mean test meal intake differed significantly by experimental condition (Table 3); the response to the conditions did not differ between men and women. Subjects consumed significantly less energy from the test meal after eating apple segments compared to the applesauce ($p < 0.01$) and both juice preloads ($p < 0.0001$). They also consumed less energy after eating applesauce compared to after drinking both types of apple juice ($p < 0.05$). Subjects ate significantly less energy from the test meal when any preload was consumed before lunch compared to control ($p < 0.0001$). Across all experimental conditions, energy intake at lunch was significantly greater for men (1132 ± 32 kcal [4.74 ± 0.13 MJ]) than for women (772 ± 24 kcal [3.23 ± 0.10 MJ]; $p < 0.0001$). Men also ate significantly more at breakfast (666 ± 13 kcal [2.79 ± 0.05 MJ]) than women (533 ± 10 kcal [2.23 ± 0.04 MJ]; $p < 0.001$), but *ad libitum* breakfast intake did not vary across conditions.

When the energy intakes from the preload and test meal were considered together, consuming apple significantly reduced total energy intake at lunch by 91 ± 24 kcal [381 ± 100 kJ] compared to consuming applesauce, by 152 ± 36 [636 ± 151 kJ] compared to apple juice with fiber, and by 178 ± 27 [745 ± 113 kJ] compared to apple juice without fiber (all $p < 0.02$; Fig. 1). Lunch intake was significantly lower when applesauce was consumed compared to both types of apple juice ($p < 0.05$); in the two juice conditions, however, total energy intakes at lunch did not differ significantly from each other. Compared to when no preload was consumed, subjects reduced total energy intake at lunch by 187 ± 36 kcal [782 ± 151 kJ] when apple was eaten, to $85 \pm 4\%$ of intake in the control condition ($p < 0.0001$; Table 3). In addition, when applesauce was eaten as a preload, total energy intake at lunch was reduced by 96 ± 29 kcal [402 ± 121 kJ] compared to control ($p < 0.01$). There were also no significant differences in lunch energy intakes across study sessions.

Analysis of covariance showed that the relationship between type of preload and energy intake at lunch was not significantly influenced by any of the measured subject characteristics (age, height, weight, body mass index, or scores for restraint, disinhibition, and hunger). There were also no significant differences in meal duration across study sessions.

Ratings of hunger, fullness, and thirst

Before the preloads were consumed, there were no significant differences in ratings of hunger, fullness, or thirst by condition. Hunger ratings (Fig. 2a) after consumption of any preload were significantly lower than after control ($p < 0.001$). Hunger was lower following consumption of apple than after applesauce, apple juice with fiber, or apple juice without fiber ($p < 0.0001$). Hunger ratings were also lower after eating applesauce than after drinking apple juice without fiber ($p < 0.01$). Hunger ratings after lunch were similar after consumption of all preloads. Compared to control (10 ± 2 mm), however, there were small but significant decreases in hunger ratings after lunch for apple and applesauce (7 ± 1 mm; $p < 0.05$). Analysis of covariance showed that energy intake at the test meal had a significant positive relationship to ratings of hunger after consumption of the preload (slope 4.6 ± 0.7 ; $p < 0.0001$).

Fullness ratings (Fig. 2b) were significantly higher after any preload was consumed compared to control ($p < 0.0001$). Fullness ratings were also significantly greater after consumption of apple compared to applesauce, apple juice with fiber, and apple juice ($p < 0.0001$), and when applesauce was eaten compared to apple juice with fiber and apple juice ($p < 0.001$). After lunch, ratings of fullness did not differ significantly between preloads, but fullness ratings were significantly higher after apple (87 ± 1 mm) compared to control (81 ± 2 mm; $p < 0.05$). Analysis of covariance showed that energy intake at the test meal had a significant negative relationship to ratings of fullness after consumption of the preload (slope -3.3 ± 0.7 ; $p < 0.0001$).

Ratings of thirst (Fig. 2c) were significantly lower following intake of apple and both juices compared to control ($p < 0.0001$), and following both juice preloads compared to applesauce ($p < 0.0001$) and apple ($p < 0.001$). Corresponding to these differences in thirst ratings, subjects consumed significantly less water at lunch when any preload was consumed (328 ± 12 g) compared to control (412 ± 26 g; $p < 0.0001$). However, differences in thirst ratings did not correspond to differences in water intake at lunch by type of preload; there were no significant differences in water intake at lunch across the different preload types (data not shown). Thirst ratings after lunch were not significantly different across experimental conditions.

Preload characteristics

Ratings of preload characteristics made at the beginning of each test condition showed some small, but significant, differences by preload type (Table 4). Ratings for pleasantness of taste were significantly higher for the apple and apple juice than for the applesauce and apple juice with fiber ($p < 0.05$). Although the preloads were equal in calories, subjects rated the apple preload as being significantly lower in calories than all other preloads ($p < 0.001$). Subjects also rated apple segments as more filling than apple juice without fiber ($p < 0.05$) and applesauce as more filling than both juice preloads ($p < 0.05$). An analysis of covariance showed that the relationship between type of preload and energy intake at lunch was not influenced by any of the ratings of preload characteristics.

Discharge questionnaire

At the end of the study, some subjects reported that the purpose of the study was to examine the effects of different forms of apple on appetite (24 subjects, 41%), or food intake (21 subjects, 36%). Four subjects (7%) noticed that there were different types of juice served in the study, but none attributed the difference to fiber content.

Discussion

This study demonstrates that consuming different forms of fruit can significantly affect satiety and energy intake at a meal. Consuming apple segments at the start of the meal reduced lunch energy intake compared to consuming the same energy and weight of applesauce or apple juice with or without fiber. When subjects ate the apple segments at the beginning of lunch, they reduced lunch energy intake by 91 kcal [381 kJ] compared to eating applesauce, and by more than 150 kcal [628 kJ] compared to drinking either version of the apple juice. Eating apple segments also resulted in higher ratings of fullness and lower ratings of hunger compared to other forms of fruit. These results build upon previous research to show that consuming fruit before a meal can enhance satiety and reduce subsequent food intake, leading to a substantial reduction in total energy intake at the meal.

Earlier studies that investigated the effects on satiety of consuming solid and liquid forms of fruit (Bolton et al., 1981; Haber et al., 1977; Mattes, 2005) found that subjects' ratings of satiety were significantly higher following intake of fruit compared to juice. The one study that examined food intake after consumption of the preloads, however, reported no differences in energy intake as measured by 24-h food diaries (Mattes, 2005). The present study expanded upon the findings of these previous studies by demonstrating that consumption of fruit in different forms led to differences in energy intake as measured under controlled conditions. In addition, the preloads consumed in previous studies were matched for a single parameter that could affect satiety: weight (Bolton et al., 1981; Haber et al., 1977) or energy content (Mattes, 2005). The present study extended those results by matching preloads for energy content, weight, energy density, fiber content, and ingestion rate.

The present study also showed that the energy content of the apple juice both with and without fiber was compensated for by a reduction in subsequent intake; thus, drinking juice as a preload did not increase total meal energy intake. A few previous studies have found that energy intake was reduced following beverage consumption (Canty & Chan, 1991; Holt, Sandona, & Brand-Miller, 2000; Rolls, Kim, & Fedoroff, 1990), while others have shown that consuming caloric beverages has little effect on food intake, resulting in increased energy intake (Almiron-Roig & Drewnowski, 2003; DellaValle, Roe, & Rolls, 2005; Flood et al., 2006; Rolls, Kim, et al., 1990). This variability in outcomes may be due to differences in beverage characteristics and experimental design. For example, it is possible that the time interval between drinking a beverage and consuming a meal may affect compensation. Beverages consumed with or between meals may be more likely to increase energy intake than beverages consumed immediately before a meal (Almiron-Roig & Drewnowski, 2003; Almiron-Roig, Flores, & Drewnowski, 2004; Beridot-Therond, Arts, & Fantino, 1998; Canty & Chan, 1991; DellaValle et al., 2005; Holt et al., 2000; Tsuchiya, Almiron-Roig, Lluch, Guyonnet, & Drewnowski, 2006). More research is needed to systematically test how consuming beverages affects energy intake and satiety.

A number of reasons have been proposed to explain the greater effect on satiety of whole fruit compared with juice. It has been suggested that these different effects are due to differences in fiber content (Bolton et al., 1981; Haber et al., 1977), which has been shown to influence energy intake and satiety (Burton-Freeman, 2000; Howarth et al., 2001). In the present study, the apple, applesauce, and apple juice with fiber contained similar amounts of fiber, but had different effects on energy intake and satiety, suggesting that the form of fruit influences energy intake independently from fiber content. It has also been suggested that juice with added fiber influences satiety more than juice without any fiber (Tiwary, Ward, & Jackson, 1997). In the present study, contrary to expectations, there were no significant differences in satiety between apple juice with and without fiber; adding fiber to the juice, however, reduced ratings of taste.

Thus, adding naturally occurring levels of fiber to a beverage may not enhance satiety, and may decrease palatability.

The various forms of fruit may also produce dissimilar effects on satiety due to differential expectations of their effects on fullness. In the present study, prior to consuming each preload, subjects were asked to rate how filling they believed the preload would be; results showed that apple segments and applesauce were perceived as being more filling than juice. Also, based on previous experiences with the foods tested in this study, subjects may have expected that the plate of apples would be more filling than the glass of juice. Subjects' ratings of thirst decreased more following consumption of both juice preloads than after eating the apple or applesauce. Therefore, it is possible that subjects perceived the beverages to be more effective at reducing thirst, while they expected the apple segments and applesauce to satisfy hunger, leading to differences in food intake and satiety (Louis-Sylvestre, Tournier, & Chabert, 1989; McEwan & Colwill, 1996).

Different forms of fruit may also have different effects on satiety due to intrinsic structural properties that affect volume and chewing. As a result of the structure provided by intact cell walls, whole apple is larger in volume than applesauce and apple juice when matched for energy content and weight. While it is likely that this difference in volume contributed to differences in satiety, it cannot provide the entire explanation because the applesauce and apple juice preloads were similar in volume, but had different effects on energy intake and satiety. In addition, consuming different forms of fruit requires different amounts of chewing. Increased chewing has been shown to initiate cephalic-phase responses involved in digestion and metabolism that could affect food intake (Lavin, French, Ruxton, & Read, 2002; Teff & Engelman, 1996; Teff, Levin, & Engelman, 1993), and previous studies have suggested that different rates of consumption may affect energy intake and satiety (Zijlstra, Mars, de Wijk, Westerterp-Plantenga, & de Graff, 2008). In the present study, ingestion rate was controlled, but chewing varied; the apple segments required substantial chewing, applesauce required minimal chewing, and the juice preloads required no chewing. As a result, the increased chewing that was required to eat the apple segments may have contributed to subsequent increases in satiety and reductions in food intake. However, more research is needed to explore how differences in cognition, volume, and chewing interact to affect food intake and satiety when different forms of fruit are consumed.

In the present study, the effect of the different forms of fruit was similar in both men and women with a range of anthropometric and psychosocial characteristics. In particular, subjects with a range of body sizes reduced energy intake after eating apple segments at the start of the meal compared to consuming no first course. It is likely, however, that for a given individual the optimal size of the first course depends on several factors, including the amount of food they usually consume at a meal (Roe, Thorwart, Pelkman, & Rolls, 1999). Further research is needed to investigate interactions between characteristics of individuals and foods that lead to a maximal decrease in energy intake at the meal.

The results from this study suggest that eating whole fruit at the start of a meal can be an effective strategy for increasing satiety and decreasing energy intake at a meal.

Fruit consumption has been associated with diets lower in energy density (Ledikwe, Blanck, & Khan, 2006), and research has shown that consuming a diet lower in energy density is related to reduced energy intake and body weight (Ello-Martin, Roe, Ledikwe, Beach, & Rolls, 2007; Ledikwe, Rolls, & Smiciklas-Wright, 2007; Rolls, Ello-Martin, et al., 2004; Rolls, Drownowski, & Ledikwe, 2005). However, more research is needed to test the effects of consuming different forms of fruit on energy intake over longer periods of time before conclusions about the role of fruit in different forms in weight management can be made (Rolls,

Ello-Martin, et al., 2004). This study adds to the research suggesting that starting a meal with a low-energy-dense food, such as soup, salad, or fruit, reduces energy intake at the meal.

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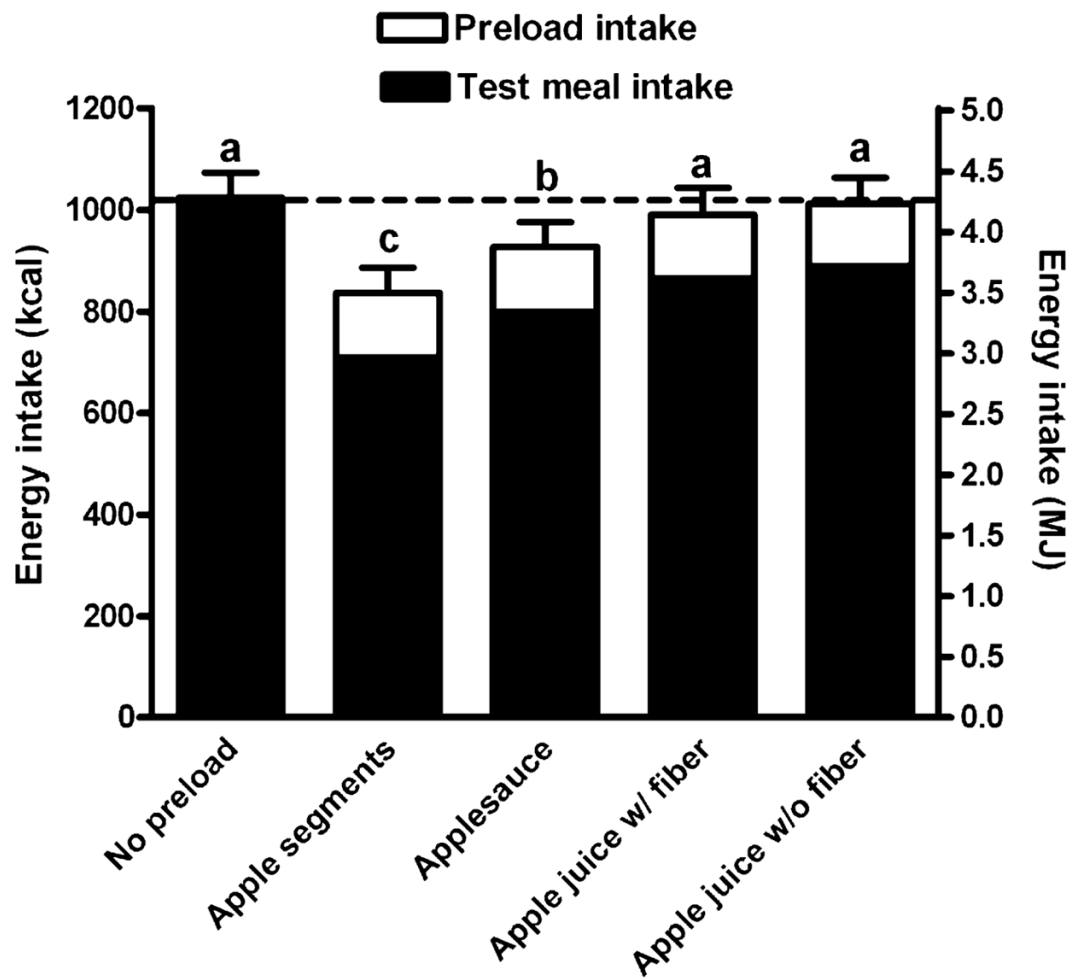


Fig. 1. Mean (\pm S.E.) total energy intake at lunch (preload + test meal) for 58 subjects in a study testing the effects on satiety of apple preloads in different forms. Preloads were matched for weight, energy, energy density, and ingestion time; the apple segments, applesauce, and apple juice with fiber preloads were matched for fiber content. Means with different letters are significantly different ($p < 0.05$) based on a mixed linear model with repeated measures.

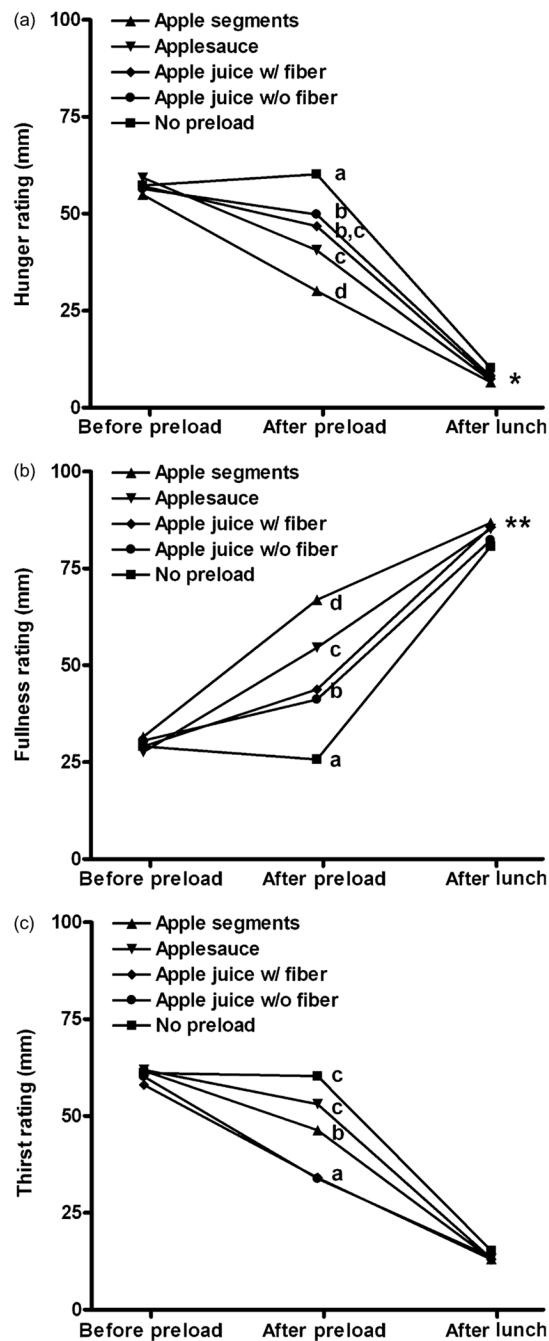


Fig. 2. Mean ratings of (a) hunger, (b) fullness, and (c) thirst across the lunch meal for 58 subjects in a study testing the effects on satiety of apple preloads in different forms. Preloads were matched for weight, energy, energy density, and ingestion time; the apple segments, applesauce, and apple juice with fiber preloads were matched for fiber content. Means with different letters are significantly different ($p < 0.01$) based on a mixed linear analysis with repeated measures. *Hunger ratings after lunch were lower when apple segments or applesauce were eaten compared to control ($p < 0.05$). **Fullness ratings after lunch were higher when apple segments were eaten compared to control ($p < 0.05$).

Table 1

Properties of preloads in a study to test the effects of different forms of apple on lunch intake of 58 subjects.

	Weight (g)	Energy (kJ)	Energy (kcal)	Fiber (g)	Energy density (kcal/g)
Apple ^a	266	536	128	4.8	0.48
Applesauce ^b	266	536	128	4.8	0.48
Apple juice with fiber ^c	266	515	123	4.8	0.46
Apple juice without fiber ^d	266	523	125	0	0.47

^a Ida Red apples without skin, Way Fruit Farm, Port Matilda, PA, USA.

^b Prepared from Ida Red apples without skin, Way Fruit Farm, Port Matilda, PA, USA.

^c Natural Apple Juice, Mott's, Rye Brook, NY with 100% apple pectin, Herbstreith & Fox, Elmsford, NY, USA.

^d Natural Apple Juice, Mott's, Rye Brook, NY, USA.

Table 2

Characteristics of 58 subjects participating in a study to test the effects of different forms of apple on lunch intake (mean \pm S.E.; range).

	Men (<i>n</i> = 30)	Women (<i>n</i> = 28)
Age (y)	26.8 \pm 0.5 (20–45)	27.1 \pm 0.6 (19–43)
Weight (kg)	76.7 \pm 0.7 (58.5–94.8)*	65.7 \pm 1.0 (45.8–96.8)
Height (m)	1.8 \pm 0.005 (1.8–1.9)*	1.6 \pm 0.005 (1.5–1.8)
Body mass index (kg/m ²)	23.7 \pm 0.2 (19.1–29.4)	24.3 \pm 0.4 (19.3–36.4)
Dietary restraint score ^a	4.5 \pm 0.3 (0–12)*	7.7 \pm 0.3 (2–17)
Disinhibition score ^a	4.4 \pm 0.2 (1–8)*	5.6 \pm 0.3 (1–12)
Hunger score ^a	4.8 \pm 0.2 (1–11)	4.8 \pm 0.2 (1–11)

^aEating Inventory (Stunkard & Messick, 1985).

* Means differ significantly between sexes ($p < 0.01$) based on a *t*-test.

Table 3

Food and energy intakes of 58 subjects participating in a study to test the effects of different forms of apples on lunch intake (mean \pm S.E.).

	Preload type				
	Control (no preload)	Apple	Applesauce	Apple juice with fiber	Apple juice without fiber
Test meal intake					
Energy (kcal)	1024 \pm 49a	709 \pm 50b	800 \pm 49c	866 \pm 52c,d	890 \pm 51d
Energy (MJ)	4.28 \pm 0.21	2.97 \pm 0.21	3.35 \pm 0.21	3.62 \pm 0.22	3.72 \pm 0.21
Weight (g)	473 \pm 22a	327 \pm 23b	369 \pm 23c	400 \pm 24c,d	411 \pm 24d
Total energy intake at lunch (preload + test meal)					
Energy (kcal)	1024 \pm 49a	837 \pm 50b	928 \pm 49c	989 \pm 52a	1015 \pm 51a
Energy (MJ)	4.28 \pm 0.21	3.50 \pm 0.21	3.88 \pm 0.21	4.14 \pm 0.22	4.25 \pm 0.21
Weight (g)	473 \pm 22a	593 \pm 23b	635 \pm 23c	666 \pm 24c,d	677 \pm 23d
Energy as % of control energy	100 \pm 0%a	85 \pm 4%b	94 \pm 4%a	99 \pm 4%a	103 \pm 4%a

For a given outcome, means that have different letters (a, b, c, d) are significantly different ($p < 0.0001$) based on a mixed linear model with repeated measures.

Table 4

Ratings of preload characteristics* (mm) taken at each test session prior to preload consumption for 58 subjects in a study to test the effects of varying the form of apples on lunch intake (mean \pm S.E.).

	Apple	Applesauce	Apple juice with fiber	Apple juice without fiber
How pleasant is the taste of this food right now?	75 \pm 2a	66 \pm 3b	59 \pm 3b	74 \pm 2a
How many calories do you think this food has?	25 \pm 2a	33 \pm 2b	37 \pm 2b	34 \pm 2b
How filling do you think this food will be?	44 \pm 3a,b	47 \pm 3a	36 \pm 3b,c	34 \pm 3c

For a given characteristic, means that have different letters (a, b, c, d) are significantly different ($p < 0.02$) based on a mixed linear model with repeated measures.

* Higher rating numbers indicate more pleasant taste, more calories, and more filling.