Citation:

Flood-Obbagy JE, Rolls BJ. The effect of fruit in different forms on energy intake and satiety at a meal. Appetite. 2009 Apr;52(2):416-22. Epub 2008 Dec 6. PubMed PMID: 19110020; PubMed Central PMCID: PMC2664987.

PubMed ID: 19110020

Study Design:

randomized crossover trial

Class:

A - Click here for explanation of classification scheme.

Research Design and Implementation Rating:

POSITIVE: See Research Design and Implementation Criteria Checklist below.

Research Purpose:

The study examined how consuming different forms of a food impacts satiety and energy intake at a subsequent meal. Also, a goal of this study was to examine how fruit affects satiety and meal energy intake.

Inclusion Criteria:

- subjects recruited from university community
- 18-45 years of age
- not taking medications 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
- free from food allergies and food restrictions
- those who reported liking apples, applesauce, and apple juice
- those who were willing to consume apples, applesauce and apple juice
- body mass index 18-40 kg/m^2
- scored <42 on the Zung questionnaire
- scored <20 on the Eating Attitudes Test
- signed consent obtained from subjects
- subjects financially compensated

Exclusion Criteria:

- less than 18 years of age or more than 45 years of age
- taking medications known to affect appetite or food intake
- smokers
- do not regularly consume three meals per day

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- dieting to gain or lose weight
- athletes in training
- have food allergies and food restrictions
- those who reported not liking apples, applesauce, and apple juice
- those who were not willing to consume apples, applesauce and apple juice
- body mass index less than 18 kg/m^2 or greater than 40 kg/m^2
- scored >42 on the Zung questionnaire
- scored >20 on the Eating Attitudes Test

Description of Study Protocol:

Recruitment

- informational flyers, electronic mailing lists and newspaper advertisements in university community
- telephone interviews were performed to ensure that respondents met inclusion criteria
- respondents who met initial criteria were screened for symptoms of depression and disordered eating using the Zung Questionnaire and 26-item verson of Eating Attitudes Test

Design: randomized crossover trial

Blinding used

No - Participants and researchers knew preload treatment

Intervention

The intervention consisted of five test sessions. On the day of each test session participants were instructed to:

- refrain from eating or drinking until provided with foods at the laboratory.
- allowed to drink water until one hour before the test session.
- refrain from drinking alcohol 24 hours before coming to the laboratory.
- avoid eating dinner at a restaurant the evening before the test session.
- keep the amount of physical activity and food intake the day before test session as conistent as possible across all test sessions. (A food and activity log was completed the day before each test session).

During each test session participants did the following:

- Completed a report to assess their compliance with the instructions provided and ensure they were feeling well.
- Breakfast of bagels and yogurt was consumed ad libitum.
- At least three hours after breakfast, lunch was served.
- Before each lunch meal, subjects consumed one of four preloads or no preload (control)
    - Apples prepared in different forms were served to participants to determine how these preloads impact satiety and meal energy intake
    - preloads were matched for energy content, weight, energy density and fiber content
    - crossover design with repeated measures : the same subjects participated in five test sessions consuming lunch preceeded by the following preloads
        - peeled apple segments
        - apple sauce

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    - apple juice
    - apple juice with added fiber
    - no preload (control)
  - random assignment was used to order the experimental conditions
- Subjects were asked to pace consumption of preloads over ten minutes or to sit and read for ten minutes if in the control condition.
- Fifteen minutes after the preload was served, subjects were served the test meal.
- Subjects were allowed to eat and drink as much or little as they wanted during the test meal period.
- Subjects rated their hunger, thirst and satiety using a series of 100-mm visual analog scales before and after breakfast, before and after the preload, and after lunch.
- Subjects rated characteristics of the preloads prior to consumption using the 100-mm visual analog scales according to pleasantness of taste, perceived calorie content, and how filling they thought the preload would be.

Description of foods and beverages used:

Preloads:

- Apples were used for all preloads . All forms of apples used were matched for weight at 266 g and energy content of approximately 125 kcal.
- Apple preload cosisted of apple segments with skin removed.
- Applesauce preload was prepared from same type of apples used in apple preload. Apples were peeled, baked and pureed. The water lost during baking was measuered and then added back to account for water loss.
- Apple juice preload was commercially made and had no measurable fiber or added sugar.
- Apple juice with added fiber preload used the same type of juice as the apple juice preload. A low-viscosity, apple-derived pectin supplement was added to this juice.
- The preloads were served at a temperature of 36°F

Test Meal:

- cheese tortellini (612 g) and tomato sauce (280 g)
- one liter of drinking water served at 2°C
- 64% energy from carbohydrate, 16% energy from fat, 20% energy from protein and energy density of 2.2 kcal/g
- Test meal provided more energy than most subjects were predicted to eat.

To determine the amount of food eaten by participants, all foods and beverages were weighed before and after being served to paricipants.

Statistical Analysis

- A power analysis was used to determine that a sample size of 51 subjects would allow the detection of a 50-kcal difference in energy intake at a significance level of 0.05 and power of 80%. This amount was considered to be a clinically significant change.
- Energy intake (kcal), food intake (g), ratings of hunger, fullness, thirst and preload characteristics were analyzed using mixed linear model with repeated measures. Fixed factor effects were preload type and subject sex.
- Overall error rate controlled using the SIMULATE adjustment in the SAS mixed model for pairwise comparisons of means in preload conditions; Dunnett-Hsu adjustment was used for comparisons to the control condition
- Participants eating <100 kcal at one or more lunch meals were excluded from analysis.

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- Analysis of covariance: to determine whether subject characteristics (height, weight, BMI, and scores for disinhibition, hunger and depression) affected relationship between preload type and main outcomes and to examine relationship between preload type and ratings of hunger, satiety

Data Collection Summary:

Timing of Measurements

Test sessions were performed once a week for five weeks.

Dependent Variables

- Variable 1: Test meal intake - energy (kcal/MJ) and weight (g)
- Variable 2: Total energy intake at lunch including preload + test meal - energy (kcal/MJ), weight (g), energy as a percent of control energy
- Variable 3: Ratings of hunger - before preload, after preload, after lunch
- Variable 4: Ratings of fullness - before preload, after preload, after lunch
- Variable 5: Ratings of thirst - before preload, after preload, after lunch
- Variable 6: Ratings of preload characteristics

Independent Variables

Preload type: apple segments, applesauce, apple juice with fiber, apple juice without fiber, no preload (control)

Control Variables

Analysis of covariance used to determine whether subject characteristics (height, weight, BMI, and scores for disinhibition, hunger and depression) affected relationship between preload type and main outcomes and to examine relationship between preload type and ratings of hunger, satiety

Description of Actual Data Sample:

Initial N: 30 males; 29 females

Attrition (final N): 30 males; 28 females

One woman did not meet minimum criteria for lunch intake of 100 kcal and was excluded from the analysis.

Age:

mean age ± S.E. =

Men: 26.8 ± 0.5 years; (age range : 20-45 years)

Women: 27.1 ± 0.6 years; (age range: 19-43 years)

Ethnicity: not described

Other relevant demographics:

body mass index kg/m^2 (mean ± S.E.):

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Men: 23.7 ± 0.2 (BMI range: 19.1-29.4)

Women 24.3 ± 0.4 (BMI range: 19.3-36.4)

mean ± S.E.:

	Men	Women
Dietary restraint score	4.5 ± 0.3	7.7 ± 0.3
Disinhibition score	4.4 ± 0.2	5.6 ± 0.3
Hunger score	4.8 ± 0.2	4.8 ± 0.2

$p<0.01$ between genders for dietary restraint score and disinhibition score

Location: university community

Summary of Results:

Key Findings:

- Consumption of apple segments decreased total lunch energy intake by 15% (187 ± 36 kcal) compared to the control ($p < 0.0001$) and decreased energy intake compared to applesauce and both juices.
- Apple segments increased satiety more than applesauce, apple juice with fiber, or apple juice without fiber.
- When fiber was added to apple juice, satiety was not increased.

Other Findings:

Test Meal intake:

- Less energy from the test meal was consumed after the preload consisting of apple segments (709±50 kcal) compared to applesauce (800±49 kcal) ($p < 0.01$) and both juice preloads (apple juice with fiber: 866±51 kcal; apple juice without fiber: 890±51 kcal) ($p < 0.0001$).
- Less energy from the test meal was consumed after the applesauce preload compared to both types of juice ($p < 0.05$).
- When any preload was consumed, participants ate less energy from the test meal than in the control condition (1024±29 kcal) ($p < 0.0001$).
- With all experimental conditions, men ate significantly more erergy at breakfast and lunch than women.
- There were not significant differences between men and women in response to the different preloads.
- There were not differences in ad libitum breakfast intake across the conditions.

Total energy intake at lunch (preload + test meal):

- apple segments significantly reduced total energy intake at lunch by:
    - 91 ± 24 kcal compared to applesauce ($p < 0.02$)
    - 152 ± 36 kcal compared to apple juice with added fiber ($p < 0.02$)
    - 178 ± 27 kcal compared to apple juice without fiber ($p < 0.02$)

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    - 187 ± 36 kcal compared to no preload -control ($p < 0.0001$)
- applesauce significantlly reduced total energy intake at lunch:
    - compared to both types of juice ($p < 0.05$)
    - by 96 ± 29 kcal compared to no preload-control ($p < 0.01$)
- total energy intake at lunch did not differ significantly between the juices with and without added fiber
- no significant differences in total energy intake at lunch were found across study sessions

Hunger

- Hunger ratings were:
    - significantly lower after consumption of any of the preloads than the control ($p < 0.0001$)
    - significantly lower after consumption of apple segments than any of the other preloads ($p < 0.0001$)
    - significantly lower after consumption of applesauce than for juice without fiber ($p < 0.01$)
    - similar with consumption of all preloads after lunch; a small, yet significant decrease in hunger ratings was present for apple and applesauce as compared to control ($p < 0.05$)
- Analysis of covariance determined 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:

- Fullness ratings were:
    - significantly higher after all the preloads than the control ($p < 0.0001$).
    - significantly higher for apple segments than other preloads ($p < 0.0001$)
    - significantly higher for applesauce than both juices ($p < 0.001$)
    - significantly higher after lunch for apple compared to control ($p < 0.05$)
- Anaysis of covariance determined 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; $p < 0.0001$)

Thirst:

- Thirst ratings were:
    - significantlly lower after apple and both juices than control ($p < 0.0001$).
    - significantly lower for both juices than for applesauce ($p < 0.0001$) and apple ($p < 0.001$).
- Less water was consumed by subjects when they ate preloads than with the control condition ($p < 0.0001$).
- Significant difference in water intakes at lunch were not found across the different preload types.
- Across the conditions, thirst ratings were not significantly different.

Preload characteristics:

- Apple and apple juice without fiber were rated as more pleasant than applesauce and apple juice with added fiber (($p < 0.001$).
- Apples segments were rated as having fewer calories than the other preloads ($p < 0.001$).
- Apple segments were rated as more filling than apple juice without fiber ($p < 0.05$).

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- Applesauce was rated as more filling than both juices ($p < 0.05$).
- Analysis of covariance determined that the relationship between preload type and energy intake was not influenced by ratings of preload characteristics.

Author Conclusion:

- Consumption of fruit before a meal can enhance satitey and in turn decrease total energy intake at the meal.
- Solid fruit enhances satiety more than pureed fruit or juice.

Reviewer Comments:

Research Design and Implementation Criteria Checklist: Primary Research

Relevance Questions

1.	Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (Not Applicable for some epidemiological studies)	Yes
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes
3.	Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to nutrition or dietetics practice?	Yes
4.	Is the intervention or procedure feasible? (NA for some epidemiological studies)	Yes

Validity Questions

1.	**Was the research question clearly stated?**	Yes
1.1.	Was (were) the specific intervention(s) or procedure(s) [independent variable(s)] identified?	Yes
1.2.	Was (were) the outcome(s) [dependent variable(s)] clearly indicated?	Yes
1.3.	Were the target population and setting specified?	Yes
2.	**Was the selection of study subjects/patients free from bias?**	Yes
2.1.	Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	Yes
2.2.	Were criteria applied equally to all study groups?	Yes

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2.3.	Were health, demographics, and other characteristics of subjects described?	Yes
2.4.	Were the subjects/patients a representative sample of the relevant population?	Yes
3.	**Were study groups comparable?**	Yes
3.1.	Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	Yes
3.2.	Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	Yes
3.3.	Were concurrent controls used? (Concurrent preferred over historical controls.)	Yes
3.4.	If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	N/A
3.5.	If case control or cross-sectional study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	N/A
3.6.	If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	N/A
4.	**Was method of handling withdrawals described?**	Yes
4.1.	Were follow-up methods described and the same for all groups?	Yes
4.2.	Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	Yes
4.3.	Were all enrolled subjects/patients (in the original sample) accounted for?	Yes
4.4.	Were reasons for withdrawals similar across groups?	N/A
4.5.	If diagnostic test, was decision to perform reference test not dependent on results of test under study?	N/A
5.	**Was blinding used to prevent introduction of bias?**	No
5.1.	In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	No
5.2.	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	No

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5.3.	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	N/A
5.4.	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	N/A
5.5.	In diagnostic study, were test results blinded to patient history and other test results?	N/A
6.	**Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were interveningfactors described?**	Yes
6.1.	In RCT or other intervention trial, were protocols described for all regimens studied?	Yes
6.2.	In observational study, were interventions, study settings, and clinicians/provider described?	N/A
6.3.	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	Yes
6.4.	Was the amount of exposure and, if relevant, subject/patient compliance measured?	Yes
6.5.	Were co-interventions (e.g., ancillary treatments, other therapies) described?	Yes
6.6.	Were extra or unplanned treatments described?	N/A
6.7.	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	Yes
6.8.	In diagnostic study, were details of test administration and replication sufficient?	N/A
7.	**Were outcomes clearly defined and the measurements valid and reliable?**	Yes
7.1.	Were primary and secondary endpoints described and relevant to the question?	Yes
7.2.	Were nutrition measures appropriate to question and outcomes of concern?	Yes
7.3.	Was the period of follow-up long enough for important outcome(s) to occur?	Yes
7.4.	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	Yes
7.5.	Was the measurement of effect at an appropriate level of precision?	Yes
7.6.	Were other factors accounted for (measured) that could affect outcomes?	Yes
7.7.	Were the measurements conducted consistently across groups?	Yes
8.	**Was the statistical analysis appropriate for the study design and type of outcome indicators?**	Yes

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8.1.	Were statistical analyses adequately described and the results reported appropriately?	Yes
8.2.	Were correct statistical tests used and assumptions of test not violated?	Yes
8.3.	Were statistics reported with levels of significance and/or confidence intervals?	Yes
8.4.	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	N/A
8.5.	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	Yes
8.6.	Was clinical significance as well as statistical significance reported?	Yes
8.7.	If negative findings, was a power calculation reported to address type 2 error?	N/A
9.	**Are conclusions supported by results with biases and limitations taken into consideration?**	Yes
9.1.	Is there a discussion of findings?	Yes
9.2.	Are biases and study limitations identified and discussed?	Yes
10.	**Is bias due to study's funding or sponsorship unlikely?**	Yes
10.1.	Were sources of funding and investigators' affiliations described?	Yes
10.2.	Was the study free from apparent conflict of interest?	Yes

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