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Effects of fruit and vegetable, consumed in solid vs. beverage forms on acute and chronic appetitive responses in lean and obese adults

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Abstract

Background—The effects of fruits and vegetables in solid vs. beverage forms on human appetite and food intake acutely and over eight weeks, are unclear.

Methods—This 21-week, randomised, crossover study assessed appetitive ratings following the inclusion of fruits and vegetables, in solid and beverage form, into the habitual diet of healthy lean (n=15) and overweight/obese (n=19) adults with low customary consumption. The primary acute outcomes were satiation (amount of challenge meal consumed), satiety (latency of subsequent eating event), and dietary compensation after a 400 kcal fruit preload. Ratings of appetite were also obtained before and after 8 weeks of required increased fruit and vegetable consumption (20% estimated energy requirement).

Results—Acutely, overweight/obese participants reported smaller reductions of hunger after consuming the fruit preload in beverage compared to solid form (preload × form × BMI effects, P=0.030). Participants also consumed significantly less of a challenge meal (in both gram and energy) after the ingestion of the solid fruit preload (P<0.005). However, the subsequent meal latency was not significantly different between the solid and the beverage fruit preloads. Total daily energy intake was significantly higher when the obese participants consumed the beverage fruit preload compared to the solid (P<0.001). Daily energy intake was markedly, but not significantly, higher among the lean with the beverage versus solid food-form. Hunger and fullness ratings remained stable when participants consumed fruits and vegetables in solid or beverage form for eight weeks each.

Conclusion—Acute post-ingestive appetitive responses were weaker following consumption of fruits in beverage versus solid food-forms. Consumption of beverage or solid fruit and vegetable food loads for 8 weeks did not chronically alter appetitive responses.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

Keywords

Solid; beverages; fruits; vegetables; appetite

INTRODUCTION

Decreasing the energy density of the diet through increased consumption of fruits and vegetables has been suggested as a method to decrease or maintain body weight (ref. 1, 2, 3, 4). The purported mechanism is based on energy displacement where foods of higher volume and lower energy density lead to decreased hunger, increased fullness, and decreased total energy intake (ref. 5, 6, 7, 8). Short-term preload and some long-term weight-loss trials provide experimental evidence to support this hypothesis (ref. 3, 7, 9, 10), but long-term, more ecologically valid data derived from trials with non-covert energy density manipulations (ref. 8, 11), using common foods such as fruits and vegetables in populations encompassing both sexes, a range of BMI categories, and minimal counseling intervention (representing the general population), are needed to verify this effect. Although the *Dietary Guidelines for Americans* (ref. 12) suggests there is strong evidence to support a relationship between low energy density and weight loss/weight loss maintenance among adults, a deeper examination of the literature suggests alternate interpretations are viable and recommendations should proceed with caution.

Well established data incongruous with the energy displacement hypothesis pose a challenge to its veracity. First, reduced food intake noted with gastric distention (ref. 13, 14, 15) may be short lived (ref. 16). Over a period longer than several hours, other factors (e.g. the absolute energy content of the meal) also contribute to satiety, particularly when low energy dense foods are included as part of the typical diet (ref. 11, 17, 18, 19, 20). Second, foods at the extremes of the energy density continuum do not support energy density as the primary control of energy intake. Due to their high water content, sweetened beverages have very low energy densities (e.g., cola = 0.4 kcal/g (ref. 21)), so they should aid weight management. However, the evidence is strong, albeit not uniform (ref. 22), that sweetened beverages elicit weak dietary compensation (ref. 23, 24, 25, 26, 27) and may promote weight gain (ref. 23, 28). In contrast, nuts have high energy density (e.g. dry peanuts = 5.8 kcal/g (ref. 21)) and should theoretically promote weight gain. To the contrary, acute feeding studies consistently demonstrate nuts are satiating (ref. 29, 30, 31) and do not contribute to weight gain (ref. 32, 33, 34, 35, 36). Third, disagreement in the literature of how to report energy density may lead to energy density associations that are of questionable practical significance. For instance, many studies reporting an association between energy density of the diet and total energy intake exclude beverages from the analysis and the relationship is not present or markedly diminished when they are included (ref. 37, 38, 39, 40, 41). It has been suggested that beverages should be removed from analyses because they add variance to data and reduce statistical power (ref. 3, 37, 42, 43, 44). A physiological rationale for this argument is lacking and is required given that energy-containing beverages now contribute ~18% of dietary energy (ref. 45). Fourth, if energy density is a primary factor affecting energy intake, there should be evidence that dietary energy density has changed over the past three decades coincident with the increased obesity incidence. Again, these data are not clear. Between the years 1971-2000, there was a decrease in the proportion of fat in the American diet, an increase in carbohydrate, and maintenance of protein and fiber (ref. 46, 47, 48). Since 2000, trends of fat and carbohydrate consumption have reversed (ref. 49) while fiber intake has remained unchanged (ref. 50). Data on total water consumption are sparse, but there is no evidence that water consumption has decreased over time (ref. 51, 52, 53). Combined, the three main contributing factors to energy density (water, fat and fiber) are unchanged or shifting in the direction opposite to the expected increasing energy density in the American diet. Overall, these observations raise questions about the long-term effects of energy displacement through consuming low energy dense foods on appetite and energy intake. Since there was a strong emphasis on energy density for weight management in the most recent *Dietary Guidelines for Americans* (ref. 2), it is critical to continue to review the applicability of this diet strategy for Americans.

Foods in beverage form are consumed faster (ref. 54) hence producing shorter oral exposure time (ref. 55), and they are emptied faster from the stomach than the solid forms (ref. 56). For these reasons, short-term trials demonstrated that energy compensation for beverage forms of fruits and vegetables (ref. 57, 58, 59) is weak in comparison to solid forms of these foods. However, long-term appetite data are needed to confirm this observation and establish its nutritional implications. Using data from a previously published study (ref. 60), the primary aim of this paper was to assess acute and chronic changes in appetite with prescribed inclusion of fruits and vegetables in solid versus beverage form in the diet. A second aim of this paper was to contrast appetitive effects between lean and overweight/obese groups, as there is evidence of weaker dietary compensation and propensity towards weight gain in individuals with higher BMI (ref. 60, 61, 62, 63).

METHODS

Experimental protocol

This protocol was a 21-week, randomised, crossover intervention with a one-week pre-intervention period (first baseline, week 1), an 8-week intervention (weeks 2-9), followed by a 3-week washout (weeks 10-12), a second one-week pre-intervention (second baseline, week 13), and second 8-week intervention (weeks 14-21). Each participant consumed their usual, unrestricted diet during the two pre-intervention weeks and the 3-week washout. They were provided portioned quantities of fruits and vegetables to consume daily along with their otherwise usual, unrestricted diet during the 8-week intervention periods. Approximately half of the participants were randomly assigned to consume isoenergetic portions of fruits and vegetables in solid (raw) form during the first intervention and in beverage form during the second intervention, while the remaining subjects completed the beverage intervention first and the solid intervention second. Selected outcomes (energy intake and body weight changes) of this study were previously published (ref. 60). In the current paper, we examine the acute and 8-week appetite-regulation aspects of the original study. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the Purdue University Institutional Review Board. Written informed consent was obtained from all participants. This trial was registered at clinicaltrials.gov as NCT00260130.

Participants

Participants (n=34, 18 females/16 males) were 18-38 years of age (mean 23±0.8 years), normal (n=15, mean BMI=20.9±0.3 kg/m^2) or overweight/obese (n=19, mean BMI=29.9±0.4 kg/m^2), weight stable during the previous 3 months, able to maintain a consistent activity pattern throughout the study, low fruit/vegetable consumption (able to comfortably double their baseline intake), not taking medications known to significantly influence appetite, non-restrained eater (<14 on restraint scale of the Three Factor Eating Questionnaire (ref. 64)), and willing to consume the required study foods. The original study required at least 27 participants to detect a difference of 1.5 kg in weight change between study groups at 80% power. Thirty-one participants completed the full protocol, while two participants completed only the beverage treatment and one completed only the solid treatment. All 34 of these participants were included in analyses by using group means in place of their missing values.

Measures

1) Acute appetite and dietary compensation—During the first and second pre-intervention baseline periods, each participant completed two days, one was without a preload and the other included a fruit preload Both entailed monitoring of short-term appetite and ingestive behavior. The day without preload acted as baseline and preceded day with preload so that participants remained naïve to the treatment. On each testing day, participants arrived at the facility at around noon, 3 hours after their usual breakfast meal. Appetite ratings before fruit preload were recorded, and this was immediately followed by consumption of an ad libitum test meal. The preloads were in solid or liquid form, and the form given during the pre-intervention corresponded to the form the participants would consume during the 8-week intervention period, determined randomly.

The solid and beverage fruit preloads contained 400 kcal (Table 1). The solid preload included a medium Gala apple, red seedless grapes, dried apples, raisins, and 470 grams of water to match the volume of the beverage preload. Forty percent of the energy was from the Gala apple and red grapes and 60% of the energy was from the dried fruit (similar to the long-term intervention). The beverage preload contained apple juice and grape juice (200 kcal of each) and 150 grams of water. Soluble fibre was added to the grape juice in an amount equal to that of the solid preload.

The challenge meal was macaroni and cheese (M&C) (Easy Mac®, Kraft Foods, Inc., Glenview, IL) (150 kcal/100g, 15% energy as fat, 12% energy as protein, and 73% energy as carbohydrate). On the fruit preload testing days, the participants were asked to consume the entire preload, immediately followed by as much M&C as they desired to reach a comfortable level of fullness (3 on a 9-point scale of arbitrary units: 1= extremely full, 9= not full at all). On the testing days without a fruit preload, the participant was asked to consume only the M&C until the same fullness level was reached. Participants were asked to pace themselves to reach a fullness sensation of "3" within 20 minutes, and all participants remained seated at the dining table for the entire 20 minutes. After completing the meal, appetite ratings were completed. Subsequently, participants recorded their appetitive responses hourly and the quantity and timing of all foods and beverages consumed for the remainder of the day away from the laboratory.

Acute appetite responses were measured as 1) hunger, 2) fullness, 3) satiation, quantified by the amount of M&C challenge meal consumed to the nearest tenth of a gram, 4) satiety, as indicated by the latency of the subsequent meal (>100 kcal) in minutes after the M&C test meal, and 5) dietary compensation (equation shown in Data Analysis). Both hunger and fullness ratings were recorded on visual analog scales (VAS) electronically on a Palm Pilot® device (Palm, Inc., Sunnyvale, CA).

2) Chronic Appetite and energy intake—During the 8-week solid and liquid fruit and vegetable exposures, appetite ratings (ref. 65) were completed on a Palm Pilot® (Palm, Inc., Sunnyvale, CA). Hunger and fullness ratings were recorded every waking hour for 24 hours during two days that included a weekday and a weekend day at the baseline, the middle, and the final week of each food-form intervention period. Pre-programmed timers reminded participants to make the hourly recordings. Most data were recorded between 10 AM to 10 PM and were included in the data analyses. Energy intake was assessed by self-administered 24-h diet records on three consecutive days which included two weekdays and a weekend day at baseline and week eight of each intervention period. The diet records were subsequently checked for accuracy by trained personnel. Compliance to dietary interventions (solid and beverage fruits and vegetables) was assessed through the measurements of plasma ascorbic acid and carotenoid (ref. 60).

During the two 8-week intervention periods, each participant was provided pre-portioned quantities of fruits and vegetables equal to 20% of their estimated energy need (calculated using the sex-specific Harris Benedict equation of resting energy expenditure multiplied by an activity factor of 1.55) rounded to the nearest 50 kcal (between 400-550 kcal/day) on a daily basis. They were provided on a weekly basis. Participants were asked to consume their daily pre-portioned fruits and vegetables only and avoid these foods from other sources.

For the solid food intervention, 10% of energy from the prescribed fruits and vegetables was provided as raw broccoli, carrots, and cauliflower, which was equivalent to approximately 1.3-2.8 servings of vegetables per day based on the USDA National Nutrient Database for Standard Reference (ref. 66). The remainder of energy was provided as fruits (40% as fresh fruit and 60% as dried fruit) which included fresh apples, grapefruit, grapes, oranges, and a variety of dried fruit (Sun-Maid®, Kingsburg, CA): apples, apricots, cranberries, mixed dried fruit, peaches, and raisins. Dried fruits, which have a higher energy density than fresh fruits, were used to help achieve the energy prescription while keeping the volume to consume reasonable. Together, the fruits and vegetables provided to the participants during the solid intervention equaled ~6-8 servings per day. Participants were allowed to select fruits and vegetables according to preference with the exception of apples and carrots (these were consumed daily by all participants, unless substituting broccoli or cauliflower for carrots).

For the beverage intervention, fruit and vegetable juices were isoenergetic to the solid food-forms. All juices were commercially available products and included: V8 Splash® (The

Campbell Soup Company, Camden, NJ), Juicy Juice® (Nestlé, Glendale, CA), Minute Maid® apple (The Coca-Cola Company, Atlanta, GA), Minute Maid® orange (The Coca-Cola Company, Atlanta, GA), grapefruit (The Kroger Co., Cincinnati, OH), Dole® grape (PepsiCo, Inc., Purchase, NY), Ocean Spray® cranberry (Ocean Spray Cranberries, Inc., Lakeville-Middleboro, MA), and Dole® pineapple (PepsiCo, Inc., Purchase, NY). Soluble fiber (Nutriose® FB 06 (Wheat Dextrin), Roquette America, Inc., Keokuk, IA), in an amount matching the corresponding fresh and dried fruits and vegetables, was added to the juice. Participants were required to consume apple juice and V8 Splash® at least four days per week, but were allowed to vary other juices according to preferences.

Data Analysis

During the acute appetite test days, dietary compensation for the lunch visits was calculated as: 100%−[((test meal total energy intake (kcal) on day with preload − test meal total energy intake (kcal) on day without preload)/(Preload energy: 400 kcal)) × 100%]. Dietary intake data were collected by 24-hour diet records and energy intake was analyzed using the University of Minnesota Nutrition Data System for Research 2005 and 2006.

Hunger and fullness ratings were collected with visual analogue scales and converted to percent of VAS line on a Palm Pilot by asking participants to answer “How strong is your 9 feeling of hunger?” and “How strong is your feeling of fullness?”. For longer-term appetite assessment, these questions were answered every hour, on the hour, for a weekday and weekend day at the baseline (week 1), middle (week 6), and end (week 9) of each intervention period. In addition, the area under the curve (AUC, determined using the trapezoidal rule) of hunger and fullness ratings reported by participants during the 8-week food-form intervention periods was also calculated for each of the two recording days, and the average AUC (weekday and weekend day) for hunger and fullness was taken for a better representation of daily appetite at the three stages (at baseline, middle, and final) of the intervention periods.

Statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS), version 16.0. The criterion for statistical significance was set at $p \leq 0.05$, two-tailed. Repeated-measures analysis of variance, with post-hoc comparisons (Bonferroni correction) when appropriate, was conducted to assess appetite and energy consumption. T-tests were used to compare satiety between treatments. Data are reported as means ± standard errors.

RESULTS

1) Acute Appetite Responses

Hunger and fullness ratings—Hunger ratings were significantly different following challenge meals with vs. without preload, for solid vs. beverage preloads as well as between lean and overweight/obese participants (repeated measures ANOVA; preload × form × BMI interaction effects, p=0.030). As shown in Figure 1, overweight/obese participants reported significantly greater hunger on the beverage fruit preload visit compared to the solid preload visit. No significant difference was noted in lean participants. A trend for a similar interaction was noted for fullness ratings (p=0.055) (results not shown).

Satiation and dietary compensation (Table 2)—There were significant preload ($F(1,64)=158.738$, $p<0.001$) effects, as well as food-form × preload ($F(1,64)=7.524$, $p=0.008$, and food-form × preload × BMI ($F(1,64)=5.638$, $p=0.021$) interactions for the amount of M&C challenge meal consumed. Without a fruit preload, the participants consumed 535±40 g and 542±32 g of the challenge meal on the testing days corresponding with the solid and beverage intervention periods, respectively. Consumption of the 400 kcal fruit preload in either form significantly decreased the amount of M&C consumed when compared to days when participants consumed only M&C without any preload, but intake suppression was greater when the preload was a solid (350±41 g or 57%5 less than without preload), versus beverage (216±20 g or 41% less than without preload) ($p=0.005$). Consumption of the challenge meal was observed to be higher after the beverage compared to the solid preload, especially in overweight/obese participants (188±44 g) but less so in lean participants (80±50 g) ($p=0.114$, NS). In the full sample, dietary compensation for the solid preload was 136±13%, but only 73±7% with the beverage reload.

Satiety or latency of subsequent meal—The time to the next eating occasion was not significantly different between days with and without preloads ($p=0.484$), between BMI groups ($p=0.722$), food-form of preload ($p=.765$), or an interaction effect among these factors (preload × BMI × food-form: $F(1,64)=0.004$, $p=0.948$). With preload in beverage form, meal latency was 270±28 min in lean and 306±37 min in overweight/obese adults (t-test, $p=0.750$). In contrast, the solid fruit preload led to a longer between-meal interval in lean (291±25 min), but shorter interval in overweight/obese (255±34 min) participants (lean vs. overweight/obese: t-test, $p=0.472$). All data combined, meal latency was 271±22 minutes for the solid and 290±24 minutes for the beverage preload (latency × BMI × food-form: $F(1,64)=0.004$, $p=0.948$).

Daily energy intakes and dietary compensation (Table 2)—There was a significant preload effect ($F(1,64)=75.429$, $p<0.001$), as well as food-form × preload ($F(1,64)=55.001$, $p<0.001$) interaction for energy intake from the challenge meal, but this interaction was not affected by the BMI status of participants ($F(1,64)=0.008$, $p=0.929$). Total daily energy consumed was higher, but not significantly, during the beverage preload visit (2729±280 kcal/day) compared to the solid preload visit (2328±123 kcal/day) (one-way ANOVA, $p=0.194$). Overweight/obese participants consumed 547±462 kcal/day more when given the beverage than the solid preload, while lean individuals consumed only 218±280 kcal/day more, but this difference was not statistically significant ($p=0.572$, NS). The total daily energy consumed was not significantly different between days with vs. no preloads, or the food-forms of preloads, although the total daily energy intake tended to be higher on days with the beverage preload. Total daily energy intake compensation was 36±59% on the beverage preload day and 133±33% on the solid preload day. There were no BMI group differences in total energy intake.

2) Longer-term Appetitive Responses (Figures 2)

There was no significant time × food-form or time × food-form × BMI interaction effects for the hunger and fullness ratings as mean percent of VAS line or AUC. However, strong and significant correlations were observed between the AUC for hunger and fullness ratings at baseline, middle, and the final week of solid and beverage exposure (fullness: baseline vs. middle, r=0.811, p<0.001; baseline vs. final, r=0.750, p<0.001; hunger: baseline vs. middle, r=0.598, p<0.001; baseline vs. final, r=0.522, p<0.001).

DISCUSSION

Short-term and some longer-term studies indicate that low energy dense foods, such as fruits and vegetables, lead to increased fullness and satiety (ref. 3, 7, 9, 10, 67). These observations have been extrapolated to long-term diet recommendations for weight loss or weight maintenance (ref. 68) with minimal data showing long-term effects on appetite and intake in representative American populations. Indeed, there is evidence that adding fruits and vegetables to the diet leads to weight loss (ref. 69, 70, 71), weight gain (ref. 72), and weight maintenance (ref. 73, 74, 75, 76).

Our data revealed lower satiation (greater M&C consumed) when fruit beverages were consumed at a lunch visit compared to when solid fruits were consumed under comparable conditions, especially for the overweight/obese participants. Satiety, as indicated by time until the next eating occasion, was not different between treatments (with or without a fruit preload). This is consistent with some other short-term data (ref. 24, 25, 77). Only beverages were associated with greater energy intake at the subsequent M&C challenge meal. The overweight/obese participants experienced smaller reductions of hunger on the beverage preload day and had higher intake of a challenge meal and markedly (about 550 kcal) higher total daily energy intake (albeit not statistically significant). The lack of statistical significance for the latter observation may reflect true lack of food form effects.

Alternatively, it may be attributable to limited statistical power as daily energy intake is highly variable and the power calculation for this study was based on body weight changes. Nonetheless, this increase is potentially clinically important as it suggests imprecise dietary compensation and this may translate into weight gain over time. Indeed, significant weight gain was observed in both the lean (+1.61±0.44 kg, p=0.003) and especially in overweight/obese (+2.22±0.47 kg, p<0.001) participants during the 8-week beverage fruit and vegetables consumption, as reported previously (ref. 60). Weight gain was due to the failure to compensate for the additional fruits and vegetables provided to the participants.

Chronic appetitive responses remained unchanged after eight weeks of fruit and vegetable consumption in both solid and beverage forms. Thus, reports that fruits and vegetables increase fullness and decrease hunger sensations (ref. 68, 78) may be mediated by acute post-ingestion appetitive regulation, rather than longer-term adjustments. Furthermore, this study demonstrated that the satiating effects of fruits and vegetables diminished when they were in an isoenergetic beverage form. Although fiber was added to beverages, it might be argued that the fiber choice did not represent fiber commonly found in fruit (i.e. pectin). However, evidence suggests that fiber added to beverages does not have an effect on satiety (ref. 79). In this study, being exposed to beverage forms of fruits and vegetables significantly increased the energy intake and body weight of lean and overweight/obese individuals after the 8-week exposure periods (ref. 60). Solid exposure increased the intake and body weight of overweight/obese, but not in lean adults. This suggests that fruits and vegetables, despite being low in energy density, did not prevent weight gain in adults who were already overweight or obese. Our findings call for careful implementation of recommendations through counseling and/or follow-up intervention to increase fruit and vegetable consumption to ensure these foods do not promote positive energy balance and weight gain.

Hunger and fullness ratings remained stable throughout the 8-week intervention periods in this study. This is consistent with observations from another study of similar study length that manipulated dietary fat intake (a high energy dense dietary manipulation)(ref. 80). However, it should be noted that there is large inter-individual variability in appetite ratings with some individuals reporting low daily mean hunger (e.g., 15-20% on a 100mm scale) and others with strong daily means (e.g., 55-60% of scale)(ref. 81). It is also notable that despite the consistency of appetitive responses over time, energy intake and body weight increased significantly in lean and especially overweight/obese adults after an 8-week exposure to beverage forms of fruits and vegetables (ref. 60). Together, these observations suggest that greater energy intake during this beverage intervention period was sought to maintain pre-exposure appetitive responses. This observation is consistent with the previous findings that liquids are less satiating and elicit weaker dietary compensation than solid food-forms (ref. 82).

It is acknowledged that the current intervention did not faithfully follow the Dietary Guidelines for Americans in variety of fruits and vegetables and recommended number of servings of fruits versus vegetables. The overall purpose of the study was to compare beverage versus solid food-forms (ref. 60). Another limitation of the present study was that participants were provided with both fruits and vegetables daily during the 8-week intervention periods to test for chronic dietary effects on appetitive responses whereas only fruits were used in the acute preload study sessions. Further, pre-study testing lead to inclusion of dried fruit, to achieve portions of fruits deemed achievable long-term in low-fruit and vegetable consumers. Additional testing of long-term appetitive effects upon addition of fruits and vegetables, completely consistent with Dietary Guidelines for Americans, is an area of future research. Interventions should include both men and women, all BMI categories, and populations who are not involved in weight-loss trials with significant dietary counseling.

CONCLUSION

In summary, our data confirm weaker acute satiation and satiety effects of beverage compared to solid food-forms of fruits as measured by appetitive responses and energy intake, especially among the overweight/obese. Over eight weeks, there was no altered chronic appetitive response upon addition of fruits and vegetables (beverage or solid) to the diet. These data suggest that implementing energy displacement strategies for weight management requires careful consideration of total energy intake.

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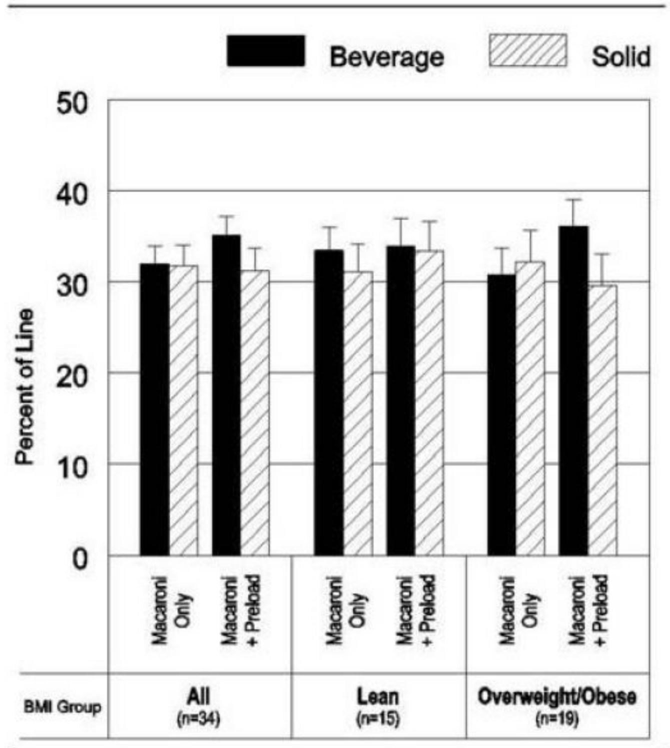

FIGURE 1. Acute hunger ratings measured as the percentage of 100mm visual analog scale used

Lunch intervention × treatment × BMI group interaction (p=0.030, n=34)

Acute hunger ratings were presented as the mean percentage of VAS scale before and after fruit preloads and hourly subsequently until 10 PM on lunch visit days.

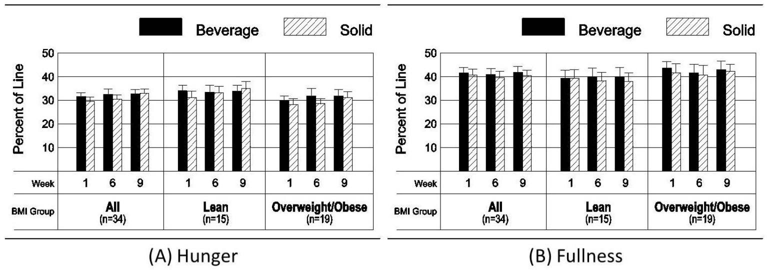

FIGURE 2. Longer-term hunger and fullness ratings, measured as the percentage of 100mm visual analog scale used, at week 1, 6, and 9 of intervention period

(A) Hunger and (B) Fullness ratings at baseline, week 6, and at final week 9 No treatment or group effects were found.

Hunger was measured for 34 human participants in a randomised-crossover trial (8-weeks for each study arm). The lean (n=15) and overweight/obese (n=19) groups were purposefully recruited and were compared to test our primary hypothesis. Data collected between 10 AM-10 PM were used for analysis.

TABLE 1

Approximate energy and macronutrient content of preload

Fruit	Mass (g)	Energy (kcal)	Carbohydrate (g)	Protein (g)	Fat (g)	Soluble Fibre* (g)
Raw apple[1]	154	80	21.3	0.4	0.3	1.1
Raw grapes[1]	119	80	20.5	0.8	0.4	0.5
Dried apples[2]	40	120	29.0	1.0	0	2.1
Raisins[2]	37	120	28.7	0.9	0	0.4
Apple Juice[2]	452	200	50.9	0	0	0
Grape Juice[2]	317	200	49.3	0.7	0	4.0

The solid and beverage preloads were matched on fruit type, energy, carbohydrate, and soluble fibre.

*Schankel et al.(78)

[1] USDA National Nutrient Database for Standard Reference(61)

[2] food label on product

TABLE 2

Acute consumption data during beverage and solid preloads

Measurement	Beverage preload + macaroni	Beverage study without preload	Solid preload + macaroni	Solid study without preload
Macaroni consumed (g)	326±29*	542±32	186±28	535±40
Satiety (minutes)	290±30	298±22	270±22	294±23
Energy intake at lunch (kcal)	891±43*	785±47	678±40	821±53
Daily total energy intake (kcal)	2729±280	2471±151	2328±123	2458±133

Data were collected during two lunch visits prior to each intervention period (n=34).

Participants consumed a macaroni and cheese meal alone on the first visit (baseline), and a solid or beverage fruit/vegetable preload (intervention) before a macaroni and cheese meal on the second visit.

* $p<0.0005$ vs. solid preload + macaroni