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Effects of portion size and energy density on young children's intake at a meal²

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Abstract

Background: Large portions of energy-dense foods are one feature of obesity-promoting dietary environments. Entrée portion size has been shown to influence energy intake at meals by young children. The role of energy density (ED) in children's response to portion size, however, is unknown.

Objective: We aimed to test the effects of portion size and ED on children's food and energy intakes at a meal.

Design: Participants were 53 (28 girls and 25 boys; 15 Hispanic, 20 black, 16 white, 2 other race) 5- to 6-y-old children [mean (\pm SD) body mass index percentile: = 61 \pm 28]. A 2 \times 2 within-subjects design was used to manipulate entrée portion size (250 compared with 500 g) and ED (1.3 compared with 1.8 kcal/g). Fixed portions of other familiar foods were provided. Weighed intake, food preference, and weight and height data were obtained.

Results: Effects of portion size ($P < 0.0001$) and ED ($P < 0.0001$) on entrée energy intake were independent but additive. Energy intake from other foods at the meal did not vary across conditions. Compared with the reference portion size and ED condition, children consumed 76% more energy from the entrée and 34% more energy at the meal when served the larger, more energy-dense entrée. Effects did not vary by sex, age, entrée preference, or body mass index z score.

Conclusions: These findings provide new evidence that portion size and ED act additively to promote energy intake at meals among preschool-aged children.

Keywords

Portion size; energy density; eating behavior; children; satiation

INTRODUCTION

Exposure to large portions of energy-dense foods may contribute to childhood obesity by promoting excessive energy intake (1,2). Secular trends reveal increases in the average size of food portions consumed by children both in and outside the home from the late 1970s through

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the 1990s (3). Experimental research has shown that doubling the portion size of an entrée increases preschool-aged children's total energy consumed at the meal by 15–39% (4,5). Recent work showed portion size effects on intake in children as young as toddlers (6). Across studies, children did not compensate for increased energy intake from large food portions by reducing the consumption of other foods. These findings suggest that large food portions can promote increased energy intake. However, evidence regarding the effects of energy density (ED; energy/g) on children's intake is less clear.

Recent findings on the effects of ED on satiation (ie, meal termination) among young children are consistent with studies in adults (7-10). When the ED of an entrée was reduced by 30%, 2- to 5-y-olds consumed 25% fewer calories (11). Alternatively, other studies of young children have shown that satiety (ie, the intermeal interval) is heightened by increasing the ED of a preload drink consumed within 1 h of an ad libitum meal (12-14). The critical question of whether children's response to large food portions is influenced by food ED has not been systematically addressed. Among adults, food ED and portion size have separate but additive effects on total energy consumed at meals (15) as well as over a 2-d period (16).

The main aim of this research was to test the effects of entrée portion size and ED on satiation in preschool children. We hypothesized that larger entrée portions would increase entrée and energy intake at the meal compared with smaller entrée portions. On the basis of recent findings on food ED and satiation in young children (11), we hypothesized that increasing the ED of an entrée would not affect children's gram intake of the entrée, consequently increasing entrée energy intake. On the basis of work in adults, we hypothesized that the intake-promoting effects of portion size and ED on entrée and meal energy intake would be independent of one another (15,16).

SUBJECTS AND METHODS

Subjects

The participants were 53 ethnically diverse (16 non-Hispanic white, 20 non-Hispanic black, 15 Hispanic, and 2 other race) 5- to 6-y-old children (28 girls, 25 boys) and their mothers living in the greater metropolitan area of Houston, TX. Exclusion criteria for the children were the presence of chronic medical conditions or medication use affecting food intake, food allergies, body mass index (BMI)-for-age <5th percentile, and dislike of the entrée. The convenience sample was recruited through flyers posted in the community as well through the US Department of Agriculture Children's Nutrition Center's website, publications, and volunteer database. The demographic characteristics of the children and their mothers are given in Table 1. On average, mothers were in their mid 30s, were overweight, and were well-educated. Children were, on average, of normal weight; 6 of 53 were overweight (BMI \geq 95th percentile).

Design

A 2 \times 2 within-subject factorial design was used to evaluate effects of portion size and ED on satiation. Each child was seen in 4 conditions differing only in the portion size (250 or 500 g) and ED (1.3 or 1.8 kcal/g) of a macaroni and cheese entrée served at a dinner meal. Consistent with the design of previous studies in children, the reference entrée portion size was doubled for the large portion condition (4-6,17). A design previously used to study ED among adults (9) was used as the basis of the ED manipulation in the present experiment; the ED of the dinner entrée varied by 40% across conditions via manipulations in fat and water content. Fixed portions of other foods and beverages were offered at each meal. Each condition was spaced 1 wk apart. Children ate in small groups of 3 to 4, with all children in a given group participating in the same condition sequence. The order of condition presentation was randomly assigned to each small group of children. Weighed intake methods were used to assess children's food

intake. Children's preferences for the entrée and for other foods offered were measured by using a tasting procedure. Height and weight measurements were obtained from children and their mothers. Mothers also provided family demographic information.

Experimental menu

A commercially available macaroni and cheese dinner (Stouffer's, Nestle USA Inc, Solon, OH) with an ED of 1.42 kcal/g was used as the base to which butter (Land O' Lakes Inc, Arden Hills, MN) was added to achieve an ED of 1.8 kcal/g (Table 2). Water was added to the unmodified macaroni and cheese base to create the reference ED version (1.3 kcal/g) of equal weight to the high-ED version. Quantitative affective sensory tests with untrained adults ($n = 16$ men, 25 women; age = 41 ± 11 y) showed no differences between versions on 100-mm visual analogue scale ratings of cheese flavor ($t = 1.12$, $P = 0.27$), color ($t = 0.58$, $P = 0.57$), oiliness ($t = -0.27$, $P = 0.79$), and pleasantness ($t = -0.42$, $P = 0.68$). Furthermore, 88% of those adults did not identify the high-ED version as containing more calories.

Entrée portion sizes were 250 and 500 g in the reference and large portion conditions, respectively. The size of the reference entrées was intended to be ample enough to avoid experimentally induced restriction of intake in the reference condition. The reference portion was similar to those used in previous studies (4,5) and fell between the 50th and 75th percentiles for macaroni and cheese consumption by 2- to 5-y-old children participating in the Continuing Survey of Food Intakes of Individuals (CSFII), 1994–1996 (18). The reference ED entrée provided 329 kcal in the reference portion size (250 g) and 658 kcal in the large portion size (500 g) conditions. The high-ED entrée provided 460 kcal in the reference portion size and 920 kcal in the large portion size conditions.

The portion sizes of other foods served at the dinner meal were generous and did not vary across conditions. The portion sizes were as follows: applesauce (112 g), 2% milk (1 carton; 240 g), carrots (39 g), corn (84 g), and cookies (3; 32 g). These foods, which provided 408 kcal, were included to minimize the possibility that any changes in entrée intake were attributable to limited food choice. Total energy provided in each condition was as follows: 737 kcal in the reference ED, reference portion size condition; 1066 kcal in the reference ED, large portion size condition; 868 kcal in the high-ED, reference portion size condition; and 1328 kcal in the high-ED, large portion size condition.

Measures

Intake of the entrée and other foods—Children's consumption of the entrée and other foods at the meal was measured by using weighed food intake data. Manufacturer's data were used to convert intake in grams to energy (kcal).

Maternal and child weight status—Trained nurses measured height to the nearest 0.1 cm and weight to the nearest 0.1 kg, both in duplicate. The 2000 Centers for Disease Control and Prevention growth charts were used to calculate age- and sex-specific body mass index (BMI) z scores for each child (19). Child overweight was defined as a BMI z score >95 th percentile. Maternal BMI was calculated as weight (kg)/height (m^2).

Child food preference—The children's preferences for the unmodified macaroni and cheese entrée as well as the other foods offered were assessed by using a tasting assessment method (20,21). Briefly, the children were presented with 2 bites of each food, were instructed to take a taste, and were then asked to indicate their preference as being either “yummy,” “yucky,” or “just okay.” To assess familiarity, the children were asked if they had ever eaten each food.

Procedures

Height and weight were measured at the Baylor College of Medicine General Clinical Research Center in Houston, TX. The children's intake at each dinner meal was measured at the US Department of Agriculture Children's Nutrition Research Center's Children's Eating Laboratory. Parents were instructed to refrain from giving their child any foods or beverages 2 h before the visit. On arrival, a research member interviewed the parent to confirm that those instructions had been followed. An introductory visit was used to familiarize the children to the eating laboratory and to obtain food preference and anthropometric data. At all visits, 3 to 4 children were served dinner together in the presence of a research staff member. The group of children to which each child was assigned and the staff member to whom each group was assigned did not vary across visits. To minimize visual comparisons of portion sizes, each child was assigned to eat with children in the same portion size condition. Children were instructed not to share food and to eat as little or as much as desired during the 20-min timed dinner. Mothers completed self-report questionnaires in an area separate from where their children ate. All procedures were approved by the Institutional Review Board at Baylor College of Medicine and were followed in accordance with its ethical standards.

Statistical analyses

Statistical analyses were performed by using SAS version 9.1 (SAS Institute Inc, Cary, NC). Two-way factorial analyses of variance (ANOVAs) were used to test effects of portion size (reference versus large), ED (reference versus high), and their interaction on children's intake of the entrée (g, kcal), other foods (g, kcal), and meal energy (kcal). Pairwise comparisons of means across conditions were assessed by using Tukey-Kramer tests. All models were adjusted for child age, sex, ethnicity (white, Black, Hispanic, and other), child BMI z score, entrée food preference (yummy or OK), and consumption of $\geq 95\%$ of the reference entrée portions. Interactions of these child characteristics with portion size and ED were also evaluated to determine whether main effects varied by those child characteristics. The significance level was set at $P < 0.05$ for main effects and $P < 0.01$ for 2-factor interactions. Data are presented as means \pm SEMs unless otherwise indicated.

RESULTS

Familiarity and liking of the foods

All children reported previously eating the entrée and other foods served at the meal. Eighty-seven percent of the children ($n = 46$) rated the commercially available, unmodified version of the macaroni and cheese as tasting "yummy" and 13% ($n = 7$) rated it as tasting "just okay." Most of the 53 children rated the other foods as tasting "yummy": carrots ($n = 28$), applesauce ($n = 39$), cookies ($n = 44$), corn ($n = 44$), and 2%-fat milk ($n = 42$).

Consumption of the reference portions

Consumption of $\geq 95\%$ of the entrée reference portions was assessed to evaluate the number of children for whom the reference serving size may have been limiting. Fourteen of the 53 children consumed $\geq 95\%$ of the entrée in the reference conditions. Children who ate $\geq 95\%$ of the reference portions did not consume more calories from other foods served at the meal than did the rest of the children ($P = 0.81$), but had higher total energy intakes ($P < 0.0001$). Children who ate the reference portions in full did not differ from the rest of the sample on the basis of age ($P = 0.53$), sex ($P = 0.76$), ethnicity ($P = 0.69$), or entrée preference ($P = 0.66$), but had higher BMI z scores ($\bar{x} \pm$ SD: 1.21 ± 1.20 compared with 0.18 ± 0.90 ; $P < 0.01$).

Effects of portion size and ED on children's food and energy intakes

A main effect of portion size on entrée gram consumption was observed. Children consumed 33% more of the entrée in the large portion conditions than in the reference conditions (210 ± 11 compared with 158 ± 11 g; $P < 0.0001$; Figure 1). Effects of portion size on gram intake of the entrée did not interact with child age ($P = 0.32$), sex ($P = 0.19$), ethnicity ($P = 0.95$), child BMI z scores ($P = 0.61$), or entrée preference ($P = 0.58$). Portion size effects on entrée gram consumption were greater among children who consumed $\geq 95\%$ of the reference portion entrées ($P = 0.01$), but remained significant when those children were removed from the analysis ($P < 0.05$). In contrast with portion size, entrée ED had no effect on children's gram intake of the entrée ($P = 0.97$). Furthermore, entrée ED did not interact with portion size to influence gram intake of the entrée ($P = 0.78$). Children's gram intake of other foods served at the meal did not vary with entrée portion size ($P = 0.57$) or ED ($P = 0.91$).

The effects of entrée portion size and entrée ED on the amount of energy that the children consumed from the entrée are depicted in Figure 2. Children consumed 33% more energy (332 ± 19 compared with 249 ± 19 kcal; $P < 0.0001$) from the entrées when served either the larger or the more energy-dense entrées than when served the reference versions. Portion size and ED did not interact to influence entrée energy intake ($P = 0.32$). Effects of portion size on children's entrée energy intake did not interact with child age ($P = 0.46$), sex ($P = 0.19$), ethnicity ($P = 0.93$), child BMI z scores ($P = 0.57$), or entrée preference ($P = 0.65$). Similarly, effects of ED on children's entrée energy intake did not interact with child age ($P = 0.38$), sex ($P = 0.32$), ethnicity ($P = 0.88$), child BMI z scores ($P = 0.38$), or entrée preference ($P = 0.64$). Both portion size ($P < 0.001$) and ED ($P < 0.01$) effects on entrée energy consumption were greater among children who consumed $\geq 95\%$ of the reference portion entrées, but remained significant when those children were removed from the analysis ($P < 0.05$ and $P < 0.05$ for portion size and ED, respectively).

Compared with the reference condition, total energy intake consumed at the meal was $\approx 15\%$ higher when the large portion entrées were served (548 ± 19 compared with 478 ± 19 kcal in the large and reference portions, respectively, $P < 0.001$). Similarly, total meal energy was 18% higher when the more energy-dense entrées were served compared with when the less energy-dense entrées were served (554 ± 19 kcal versus 471 ± 19 kcal in large and reference portions respectively, $P < 0.0001$). The effect of entrée portion size on total meal energy was independent of entrée ED ($F = 0.80$, $P = 0.37$). Effects of portion size and ED on total meal energy did not interact with child age, sex, entrée preference, ethnicity, or child BMI z scores (data not shown). ED effects on meal energy were greater among children who consumed $\geq 95\%$ of the reference portion entrées ($F = 6.90$, $P < 0.05$), but remained significant when those children were removed ($F = 4.30$, $P < 0.05$).

Compared with the condition in which the entrée was of a reference portion and ED condition, entrée energy consumption was 76% greater (382 ± 23 kcal versus 217 ± 23 kcal) and total energy intake at the meal was 34% greater (598 ± 24 kcal versus 445 ± 24 kcal) when the larger portion of the more energy dense entrée was served.

DISCUSSION

The present findings provide new evidence of elevated meal energy consumption by young children when served large portions of energy-dense entrées. In this study, the children's intake of a dinner entrée increased by 33% when its portion size was doubled. Similarly, energy consumed from the entrée was increased by 33% when its ED was increased by 40%. The effects of portion size and ED on children's eating were independent of one another but acted additively to promote entrée and meal energy consumption. Entrée energy intake was increased by $\approx 75\%$ and total meal energy increased by almost 35% when the entrée ED and portion size

were simultaneously increased. A similarly designed adult study produced comparable findings; energy intake at the meal was 56% greater when a large portion (900 g) of an energy-dense entrée (7.32 kJ/g) was served than when a smaller portion (500 g) of a less energy-dense entrée (5.23 kJ/g) was served (15).

The 15% increase in total meal energy observed in the large portion conditions is consistent with previous experimental studies of children in which meal energy increased by 13–39% when the portion size of a main lunch or dinner entrée was doubled (4-6). That the effects were observed even after excluding “plate cleaners” from the analyses indicates that the results were not attributable to an artificial restriction of the entrée portion size in the reference portion size conditions. Consequently, intake of the large entrée portions appeared to be excessive relative to that of the smaller portions. Limited evidence indicates that the promotion of intake by large portions may extend beyond meals to influence total daily energy intake among children. CSFII data (1994–1996, 1998) showed that the average portion size of foods consumed explained between 17% and 19% of the variance in daily energy intake among preschool-aged children (22). Experimental research has shown a 9% increase in daily energy intake among African American and Hispanic preschoolers when the portion sizes of entrées and a snack served over a 24-h period were doubled (17). Adult studies have also shown portion size effects on energy intake over 2- (23) and 11-d (24) periods, when all food and beverage portions were increased. The present results clarify implications for energy balance in children by demonstrating that large portions exerted the greatest effects on meal energy when energy-dense.

Observational studies of free-living dietary intake among young children show a positive correlation between dietary ED and daily energy intake (25,26). The present findings are among the first to experimentally demonstrate that processes leading to meal termination (ie, satiation) by young children are relatively insensitive to food ED. Children neither consumed fewer grams of the entrée when its ED was increased by 40% nor ate less of other foods served at the dinner meal. As a result, entrée and meal energy intakes were greater when the more energy-dense entrées were served. Adult ratings of the entrées, obtained as part of this research, indicate that the results were not likely explained by sensory differences between the reference and high-ED versions. The observed effect of entrée ED on meal energy is congruous with the findings of a recent study of 2- to 5-y-olds using a similar ED manipulation (11). In that study, children consumed 25% less energy at meals when served a 1.4-kcal/g entrée than when served a 2.0-kcal/g entrée. The present findings are also in general agreement with adult studies; a consistent weight (volume) of food was consumed at single and multiple meals when the ED of a given menu was systematically varied (7-10; *see* reference 27 for a review).

The mechanisms by which ED exerts an influence on children's energy intake remain poorly understood. In contrast with effects on satiation, experimental studies of satiety (ie, the inter-meal interval) in young children have shown that subsequent ad libitum intake is suppressed in response to increases in the ED of fixed portions of foods consumed as preloads. In that work, preschool-aged children accurately adjusted their ad libitum energy intake at a meal (12,13) and across successive meals (28) to achieve constant energy intake across conditions of varying preload ED; this sensitivity, however, appears to decrease with age (29). After a preload, there is a greater opportunity for feedback from post-ingestive signals than in studies of meal termination during ad libitum consumption. It is possible that post-ingestive signals from food ED inhibit appetitive drive but are less tightly controlled than those processes that defend against energy deficit (30). Additional research is needed to understand the basis of apparent differences in effects of food ED on young children's satiation and satiety.

Limited evidence suggests that overweight individuals consume larger food portions and have more energy-dense diets. Data from the CSFII, 1994–1996 and 1998, show that heavier toddlers (31) and adolescents (32), but not preschoolers (32), consumed larger food portions. A relation

between child weight status and dietary ED has not been established. Among adults, however, weight status has been positively associated with dietary ED, both with (33) and without the inclusion of energy-containing beverages (34). In the present study, interactions of child weight status with portion size and ED were not significant. Consistent with previous laboratory studies (5,6,17), these findings indicate that the effects of portion size and ED were not moderated by child weight status. In other words, overweight and nonoverweight children appear to respond similarly to large food portions in the laboratory. As such, the observation that heavier children consume large food portions (31,32) may reflect greater routine exposure to large portions foods rather than a weight-based susceptibility to overconsume them.

The use of a small convenience sample in this research limits the generalizability of the findings. Because preference data were obtained only for the unmodified version of the macaroni and cheese entrée, the extent to which differences in children's intake of the reference and high-ED entrées were due to preference is not possible to discern. Adult sensory ratings of the entrées, however, suggest that any such differences were minimal. A final consideration is that 25% of the sample consumed the reference entrée portions in full. In contrast with previous studies (5,6), the "plate cleaners" consumed significantly greater amounts of the entrée in response to increasing portion size and ED than the rest of the children. It is not possible to discern the extent to which the intake of "plate cleaners" was restricted by the reference portions. The main findings, however, were unchanged when the data from children who consumed $\geq 95\%$ of the reference portions were excluded. Future work is needed to understand how "plate cleaners" respond to increasing food portion size.

In conclusion, this study revealed independent and additive effects of entrée portion size and ED on young children's entrée intake and total energy consumed at the meal. These results support the perspective that large portions of energy-dense foods foster obesigenic eating behavior among young children by promoting energy intake at meals.

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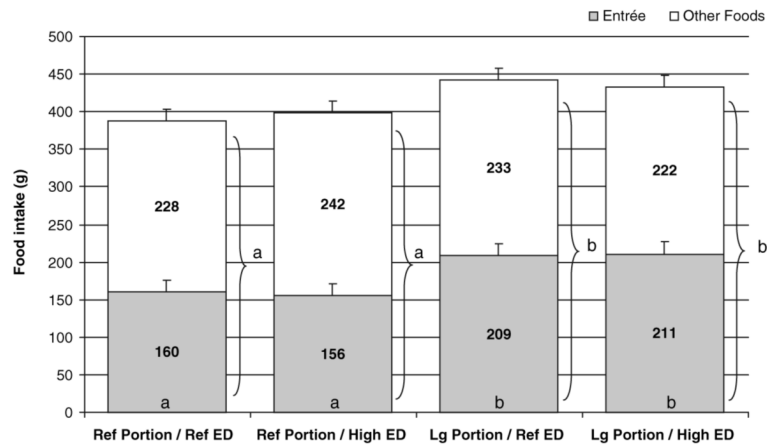


FIGURE 1.

Effects of portion size and energy density (ED) on food intake. Ref, reference; Lg, large. ANOVA was used to test the effects of portion size and ED on food intake, adjusted for child's age, sex, ethnicity, BMI z score, entrée preference, and eating $\geq 95\%$ of the reference portions ($n = 53$). Data are presented as LS means (\pm SEMs); different letters signify mean differences, $P < 0.01$. Main effects of portion size on entrée intake in grams ($F = 21.25$, $P < 0.0001$) and total grams consumed at the meal ($F = 9.04$, $P < 0.01$) were observed. Portion size did not affect gram intake of other foods ($F = 0.32$, $P = 0.57$). ED did not affect gram intake of the entrée ($F = 0.00$, $P = 0.97$), other foods ($F = 0.01$, $P = 0.91$), or the total grams consumed at the meal ($F = 0.00$, $P = 0.95$). Portion size effects on food intake did not interact with ED.

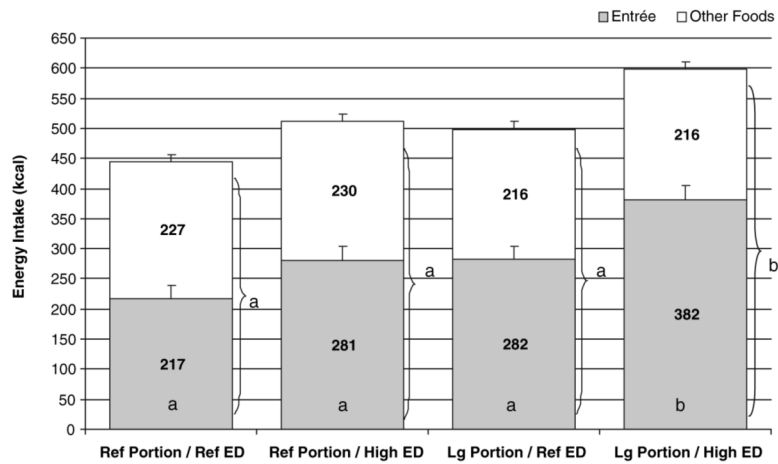


FIGURE 2.

Effects of portion size and energy density (ED) on energy intake. Ref, reference; Lg, large. ANOVA was used to test the effects of portion size and ED on energy intake, adjusted for child's age, sex, ethnicity, BMI z score, entrée preference, and eating $\geq 95\%$ of the reference portions ($n = 53$). Data are presented as LS means (\pm SEMs); different letters signify mean differences, $P < 0.01$. Main effects of portion size on entrée energy intake ($F = 19.87$, $P < 0.0001$) and total meal energy ($F = 13.34$, $P < 0.001$) were observed. Main effects of ED on entrée energy intake ($F = 19.79$, $P < 0.0001$) and total meal energy ($F = 19.07$, $P < 0.0001$) were observed. Neither portion size ($F = 1.55$, $P = 0.21$) nor ED ($F = 0.01$, $P = 0.92$) affected the energy intake of other foods. Portion size effects on energy intake did not interact with ED.

TABLE 1

Family demographics¹

| | Value |
|---|---------------------------------|
| Married [<i>n</i> (%)] | 42 (80) |
| Education > high school [<i>n</i> (%)] | 41 (79) |
| Maternal age (y) | 35.9 ± 6.2 (23–47) ² |
| Maternal BMI (kg/m ²) | 30.8 ± 6.4 (19.1–46.1) |
| Child BMI percentile | 61.4 ± 28.4 (1.91–99.9) |
| Child BMI <i>z</i> score | 0.45 ± 1.08 (–2.07–3.32) |

¹
n = 53.

²
 $\bar{x} \pm \text{SD}$; range in parentheses (all such values).

TABLE 2

Entrée ingredient and nutrient profiles

| | Reference energy density (1.32 kcal/g) | | High energy density (1.84 kcal/g) | |
|------------------------|--|---------------|-----------------------------------|---------------|
| | 250-g portion | 500-g portion | 250-g portion | 500-g portion |
| Ingredients (g) | | | | |
| Macaroni and cheese | 231.8 | 463.6 | 231.8 | 463.6 |
| Water | 18.2 | 36.4 | — | — |
| Butter | — | — | 18.2 | 36.4 |
| Nutrients | | | | |
| Energy (kcal) | 329 | 658 | 460 | 920 |
| Fat (g) | 15.4 | 30.8 | 29.7 | 59.4 |
| Carbohydrate (g) | 31.9 | 63.8 | 31.9 | 63.8 |
| Protein (g) | 15.4 | 30.8 | 15.4 | 30.8 |