Appetite. Author manuscript; available in PMC 2007 December 11.

Published in final edited form as:
Appetite. 2007 May ; 48(3): 351–358.

Incorporation of air into a snack food reduces energy intake

Kathrin M. Osterholt, MS[a], **Liane S. Roe, MPH, RD**[a], and **Barbara J. Rolls, PhD**[a]

a *Department of Nutritional Sciences, The Pennsylvania State University, 226 Henderson Building, University Park, PA 16802-6502, USA.*

Abstract

This study investigated how the air content of a familiar snack food affected energy intake and whether varying the method of serving the snack modified intake. We tested two versions of an extruded snack (cheese puffs) that were equal in energy density (5.7 kcal/g), but differed in energy per volume (less-aerated snack: 1.00 kcal/ml; more- aerated snack: 0.45 kcal/ml). In a within-subjects design, 16 women and 12 men consumed the snacks *ad libitum* in the laboratory during four afternoon sessions. A standard volume (1250 ml) of each snack was served once in a bowl and once in an opaque bag. Results showed that intake of the two snacks differed significantly by energy ($p=0.0003$) and volume ($p<0.0001$); subjects consumed 21% less weight and energy (70±17 kcal) of the more-aerated snack than the less-aerated snack, although they consumed a 73% greater volume of the more-aerated snack (239±24 ml). These findings suggest that subjects responded to both the weight and volume of the snack. Despite differences in intake, hunger and fullness ratings did not differ across conditions. The serving method did not significantly affect intake. Results from this study indicate that incorporating air into food provides a strategy to reduce energy intake from energy-dense snacks.

Keywords

food volume; food weight; portion size; energy intake; food intake; air content; visual cues; snacks; snacking

Introduction

Reported consumption of snack foods, particularly of high-fat salty snacks, has increased since the late 1970s (Zizza et al., 2001; Nielsen & Popkin, 2003; U. S. Department of Agriculture, 1999), and this has been paralleled by an increase in obesity rates in the United States (Ogden et al., 2006). The suggestion that snacking might contribute to this rise in obesity rates is supported by a study showing that snacking frequency was higher in obese than normal-weight individuals and was associated with higher energy intakes (Berteus Forslund et al., 2005). High-fat snack foods are potentially problematic for the regulation of energy intake because they are high in energy density (kcal/g) and very palatable. In addition, there is evidence that consuming a snack in a non-hungry state does not delay the start of nor reduce energy intake at the subsequent meal (Marmonier et al., 1999 and 2002). These findings suggest that research is needed to find strategies to decrease energy intake from snack foods.

There is some evidence that food intake is influenced by both the weight and volume of foods. Several studies have indicated that individuals consume a consistent weight of food over a

Correspondence to: Barbara J. Rolls, bjr4@psu.edu.

period of up to two weeks, despite differences in the energy density or macronutrient composition of the food (Bell et al., 1998; Miller et al., 1998; van Stratum et al., 1978; Duncan et al., 1983; Stubbs et al., 1995a; Stubbs et al., 1995b; Stubbs et al., 1996). Although the volume of a food is usually proportional to its weight, the incorporation of air (which adds volume but not weight) allows the dissociation of food weight and food volume. In one experiment in men, increasing the volume of yogurt-based iso-energetic preloads by increasing the amount of incorporated air led to a reduction in subsequent energy intake at lunch (Rolls, Bell, & Waugh, 2000). Foods with irregular shapes also are associated with a larger volume for a given weight of food since they do not compact easily. In a study of the effect of energy density on *ad libitum* intake it was observed that volume and weight were disproportional for two versions of an entrée, and that subjects ate a consistent volume but not weight of food (Bell & Rolls, 2001). The disparity between volume and weight of the entrées was due to the higher proportion of irregularly-shaped ingredients in one version, which therefore did not compact as readily as the other. These studies show that volume, independent of weight, can have an effect on food and energy intake. Further studies are needed, however, to elucidate the role of food volume in the regulation of food intake.

Several studies suggest that intake is influenced by the visual cues available during consumption. Two studies that tested the effect of removing all visual cues by blindfolding subjects found that food intake was decreased by 22 to 24% compared to when eating without the blindfold (Linné et al., 2002; Barkeling et al., 2003). In another study, however, subjects consumed less of a liquid diet when they could see the food reservoir compared to when it was hidden (Shaw, 1973). These studies used methods that disrupted normal eating behavior and completely removed visual cues during food consumption. Therefore, studies modeling more naturalistic variations in visual cues, such as when eating from an opaque package compared to an open bowl, are needed.

The purpose of the present study was to test how short-term *ad libitum* intake is affected by variations in the air content of a snack food. On different occasions, subjects were provided with the same volume of a more-aerated and a less-aerated version of the snack, each served once in an opaque bag and once in a bowl. It was hypothesized that subjects would eat a consistent volume of both types of snack, so that energy intake would be lower for the snack with the higher air content. It was further hypothesized that serving the snacks in an opaque bag would lead to increased intake compared to presenting them in an open bowl, since there would be fewer visual cues about the amount consumed.

Methods

Subjects

Potential subjects were recruited by newspaper advertisements and through university e-mail lists. Respondents were interviewed by telephone to ensure that they met the inclusion criteria: aged 19 to 45 y, were in good health, were not dieting to gain or lose weight, were not in athletic training, were not pregnant or lactating, were not using medication known to affect appetite or food intake, were non-smoking, regularly ate lunch, regularly ate a salty snack in the afternoon, and liked the study foods. Potential subjects came to the laboratory to complete questionnaires, to have their height and weight measured, and to rate their preference for the snack foods. A similar number of subjects of each sex who preferred each snack were recruited.

Individuals were not included in the study if their body mass index (BMI) was outside the range of 19–40 kg/m^2; if they scored ≥20 on the Eating Attitudes Test (EAT-26), which measures aberrant attitudes toward food and eating (Garner & Garfinkel, 1979; Koslowsky et al., 1992); or if they scored ≥40 on the Zung Self-Rating Questionnaire, which assesses symptoms of depression (Zung, 1986). Subjects also completed a Demographic and Health

Questionnaire and the Eating Inventory (Stunkard & Messick, 1985), which measures dietary restraint, disinhibition, and hunger. Subjects with a range of scores for dietary restraint were included in the study. Subjects were told that the purpose of the study was to test the effects of eating snacks, and were financially compensated for their participation. All aspects of the study were approved by the Office for Research Protections of The Pennsylvania State University.

Design

The experiment used a cross-over design with repeated measures within subjects. Subjects reported to the laboratory to consume a snack on 4 separate afternoons at least 3 days apart. On each occasion, subjects were served a similar volume of one of two extruded snacks differing in amount of incorporated air, which were presented either in a bowl or a sealed opaque bag. The order of presentation of the snacks and serving methods was randomized across subjects. Subjects could consume as little or as much of the snack as they desired.

Test foods

The snacks used in this study were cheese-flavored extruded corn snacks that were made from the same ingredients but differed in the amount of incorporated air (less-aerated: Cheetos Crunchy, Frito Lay, Inc., Plano, TX, USA; more-aerated: Cheetos Puffs, Frito Lay, Inc., Plano, TX, USA). Characteristics of the snacks are shown in Table 1. Both snacks had an energy density of 5.7 kcal/g and contained 56% of energy as fat. The snacks differed slightly in sodium content (less-aerated: 1.0% of weight; more-aerated: 1.3% of weight). Subjects were served the same volume of each snack (approximately 1250 ml), but received 55% less weight and energy when served the more-aerated snack rather than the less-aerated snack. Thus if subjects ate a consistent weight, they would consume the same energy of both types of snack while consuming more than double the volume of the more-aerated snack, whereas if they ate a consistent volume, they would consume 55% less energy and weight of the more-aerated than of the less-aerated snack. The extent of visual cues was varied by serving the snacks either in a wide and open white quart bowl (Corelle®, World Kitchen, Inc., Endicott, NY, USA) or in a sealed, unlabelled opaque 8- by 12-inch metallized polyester bag (SilverPAK®, Kapak Corporation, Minneapolis, MN, USA).

Procedures

Subjects were instructed to eat a similar lunch 2 to 3 hours before each test session and to refrain from consuming any energy-containing beverages or food between lunch and the test session. They were also asked to refrain from drinking alcohol during the 24 h before the test session and to maintain a similar pattern of physical activity on test days. Subjects reported to the laboratory at their scheduled snack time between 2 and 3:30 p.m. and were interviewed about their lunch intake, physical activity, physical well-being, and intake of medication on that day, as well as any food intake between lunch and the test session. Subjects who failed to comply with the study protocol were excluded from the study.

Subjects were seated in individual cubicles and served the specified weight of one of the two snacks in either a bowl or a sealed bag, along with 1 L of water. Subjects were instructed to eat directly from the bowl or the bag (after opening it and placing it on the serving tray), and to consume as little or as much of the snack and water as they desired. In order to assure that subjects were exposed to the snack for the same length of time they were required to remain in the cubicle for 12 min; the duration of the snack session was determined after preliminary tests. Subjects who consumed the entire amount of snack at one or more sessions were excluded from the analysis because the amount that they desired to eat may have been limited by the quantity that was served.

The snack food and water were weighed before and after each session to determine the weight consumed to the nearest 0.1 g. Energy intake was determined from the weight consumed using data from the food manufacturer. Mean weight per volume of each type of snack (g/ml; Table 1) was estimated by measuring the weight of ten samples of a given volume; these values were used to calculate the volume consumed of each snack from the weight consumed. Mean weight of a single piece of each snack (g/piece; Table 1) was determined by counting the number of snack pieces in five samples of a given weight. These values were used to calculate the number of pieces consumed of each snack from the weight consumed.

Before and after each snack session, subjects rated their hunger, fullness, perception of how much they could eat (prospective consumption), thirst, and nausea using 100-mm visual analog scales. Immediately before and after the snack was eaten, subjects also rated the pleasantness of taste, energy content, and serving size of the snack (compared to their usual portion), again using 100-mm visual analog scales. At the end of the study, subjects completed a discharge questionnaire, which asked what they thought the purpose of the study was and if they noticed any differences between the test sessions.

Statistical analysis

A mixed linear model with repeated measures was used to analyze the main outcomes of intake by weight (g), energy (kcal), and volume (ml), as well as the secondary outcomes of intake by number of pieces, ratings of hunger and satiety, and ratings of snack characteristics. Fixed factor effects were snack type, serving method, and subject sex; subjects were treated as a random effect. Covariate analyses were conducted to determine whether the relationship between the fixed factors and the main outcomes was affected by any continuous subject characteristics (age, weight, BMI, taste ratings before snack consumption, or scores for dietary restraint, disinhibition, hunger, depression, or eating attitudes). Subject characteristics for men and women were compared using *t*-tests. Differences in means were considered significant at $p < 0.05$. Data were analyzed using SAS System for Windows (version 9.1; SAS Institute Inc., Cary, NC, USA).

Results

Subject characteristics

Thirty-six subjects were enrolled in the study. Four subjects were excluded from the study because of non-compliance with the study protocol. A further four subjects (1 woman and 3 men) were excluded from the analyses because at one or more sessions they consumed the entire snack (1250 ml); in all instances, the snack fully consumed was the more-aerated snack. The final sample consisted of 28 subjects; their characteristics are shown in Table 2.

Snack intake

The degree of aeration of the snacks had a significant effect on the weight and energy consumed ($p = 0.0003$; Figure 1a) as well the volume consumed ($p < 0.0001$; Figure 1b). Regardless of the serving method, subjects consumed a mean of 70 ± 17 fewer kcal of the more-aerated snack than the less-aerated snack, equivalent to a 21% decrease in energy intake. When assessed by volume, however, consumption of the more-aerated snack was 239 ± 24 ml greater, equivalent to a 73% increase in the volume consumed. Subjects consumed an estimated 68 ± 4.3 pieces of the less-aerated snack and 24 ± 1.3 pieces of the more-aerated snack ($p < 0.0001$). Thus compared to the less-aerated snack, subjects consumed a greater volume but less weight, energy, and number of pieces of the more-aerated snack. There were significant differences between women and men in the amount of snack consumed, but no significant difference between women and men in the effect of degree of aeration on snack consumption (Table 3). The serving method of the snack had no significant effect on snack intake by weight and energy or by volume (Table 3). There was no significant effect of sequential test session on snack intake or any interaction of test session with the experimental variables. Water intake was 63 ± 18 ml greater ($p = 0.002$) when subjects ate the more-aerated snack compared to the less-aerated snack.

Analysis of covariance showed that none of the measured subject characteristics (age, body weight, BMI, or scores for dietary restraint, disinhibition, hunger, depression, or eating attitudes) affected the relationship of snack type to intake, whether assessed by weight, energy, or volume. Neither did taste ratings before snack consumption affect the relationship of snack type to intake by weight, energy, or volume.

Subject ratings of snack characteristics and hunger and satiety

Subject ratings of pleasantness of taste of the more-aerated and less-aerated snacks did not differ significantly either before consumption (70.0 ± 2.9 mm vs. 69.6 ± 3.0 mm) or after consumption (50.2 ± 3.2 mm vs. 53.6 ± 3.5 mm). Neither did the decline in ratings of pleasantness of taste from before to after consumption differ by snack type. Before snack consumption, subjects rated the less-aerated snack to be larger in serving size (compared to their usual portion) than the more-aerated snack ($p = 0.003$; Figure 2a), although the volumes served were similar. In contrast, subjects did not rate the less-aerated snack to be greater in energy content than the more-aerated snack before consumption ($p = 0.28$; Figure 2b), although it contained 2.2 times as much energy.

Before consumption of the snacks, there were no significant differences across experimental conditions in subject ratings of hunger (mean 43.1 ± 2.3 mm) or fullness (48.4 ± 2.3 mm). Despite significant differences in intake of the two snacks, after consumption there were no significant differences between the less-aerated and the more-aerated snacks in subject ratings of hunger (17.4 ± 2.3 mm vs. 15.3 ± 1.9 mm) or fullness (77.6 ± 2.2 mm vs. 78.9 ± 2.3 mm).

Discharge

Five subjects (18%) correctly identified that a purpose of the experiment was to investigate the effects on snack intake of differences in volume or air content of a snack or method of serving the snack. The remaining 23 subjects (82%) had no idea or incorrect ideas about the purpose of the study. The effect of snack type on intake was significant both for subjects who were and were not aware of the correct purpose of the study. Twenty-six subjects (93%) noticed differences between the sessions regarding serving method or snack type, and two subjects (7%) reported that they did not notice any differences between the sessions.

Discussion

This study demonstrated that a difference in the air content of a snack food affected the energy, weight, and volume consumed when equal volumes of two types of snack were served and consumed *ad libitum* by non-dieting individuals. Subjects reduced their energy intake by 70 kcal (21%) when they were served the more-aerated snack rather than the less-aerated snack. The decrease in food and energy intake was significant even though subjects responded to the manipulation by eating a significantly greater volume of the more-aerated snack (73%). The results indicate that subjects partially adjusted their snack intake both by weight and by volume, but that intake was more consistent by weight than by volume.

These results confirm and extend findings from previous studies indicating that the amount of air incorporated into food can affect energy intake. In one study, increasing the volume of a liquid yogurt-based preload by incorporating air resulted in enhanced satiety and decreased energy intake at a lunch 30 min later (Rolls, Bell, & Waugh, 2000). In another study, it was observed that two versions of an entrée were disproportional in volume and weight, and that *ad libitum* intake of the two versions was similar by volume but not by weight (Bell & Rolls, 2001). In that study the difference in weight per volume was small (a 19% decrease) and the food was relatively unfamiliar (taco salad). In the present study the food tested was a familiar savory snack and the two versions had a large difference in weight per volume (a 55% decrease). These findings suggest that if individuals are unaware of differences between foods, for example when eating an unfamiliar food with a small change in weight per volume, they adopt a strategy of consuming a consistent volume. When consuming a familiar food with an obvious difference in air content, however, individuals tend to eat a more consistent amount by weight. Thus, the current evidence indicates that the volume of food influences energy intake, but the effect may depend upon a number of factors, including when the food is consumed, the magnitude of the difference in volume, and cognitive cues such as the familiarity of the food.

In this study, in which *ad libitum* consumption was measured over a short time period, intake was likely to be influenced more by cognitive and sensory cues than post-ingestive signals. Visual cues that could be used to guide intake were varied by serving the snack either in an opaque bag or an open bowl; these two methods of serving the snack did not have a significant influence on intake. This differs from previous studies in which a reduction in visual cues was found to influence food intake (Barkeling et al., 2003; Linné et al., 2002; Shaw, 1973). Previous studies, however, involved a substantial disruption of normal eating conditions and a complete removal of visual cues related to the amount of food that was available. The present study tested two typical ways of serving snacks, both of which provided visual information concerning the amount of food present, but to a different extent. A possible reason for the lack of effect of serving method is that the experiment focused on intake in the absence of environmental distractions and tested a single food with which subjects had previous experience. Not only were subjects familiar with the test foods at the start of the study, but they gained more experience with them during the study. Thus, visual and oro-sensory cues associated with snack consumption as well as cues obtained by handling the snacks may have combined to influence intake despite the difference in serving method.

Subjects consumed a greater volume of the more-aerated snack than the less-aerated snack, but the magnitude of the increase was insufficient to equalize energy intake from the two snack types. Portion size ratings provide evidence that subjects had some idea of the differences between the snack types in weight and energy per volume. However, this awareness was not reflected in ratings of energy content of the two snack types. Thus subjects were aware of some of the differences between these familiar snack types, but did not translate these into an accurate adjustment of energy intake.

The finding that ratings of hunger and fullness at the end of the snack were similar despite differences in energy intake indicates that aeration can influence these sensations. In addition, aeration did not affect the change in the ratings of the pleasantness of the taste of the snack after it was consumed. Typically, as a food is eaten, the pleasantness of its taste decreases, and this is a factor limiting further intake of that food (Rolls, 2000). Such changes in perceived pleasantness have been found to be affected by the volume of food consumed (Bell, Roe, & Rolls, 2003). Associations between the amount of food consumed and changes in hunger, satiety, and palatability can be disrupted by the perception of the energy content of foods (Rolls et al., 1992) as well as environmental food cues such as the portion served (Rolls, Morris, & Roe, 2002). The present study shows that aeration of food can also disrupt these associations, and adds to the evidence that the way a food is perceived influences its evaluation both in terms of hedonics and satiety.

Because this was a study of *ad libitum* intake, we ensured that the two snacks were similar in macronutrient content and were rated similarly in palatability. The snacks differed, however, in several properties in addition to the degree of aeration (such as sodium content and texture), thus a role for these factors in influencing the outcome cannot be excluded. The snacks also differed in the size of the individual pieces and the number of pieces that were served. Several researchers have suggested that individuals might consume a constant number of pieces or units of similar foods, despite variations in the size of the units (Nisbett, 1968; Herman & Polivy, 2005; Geier, Rozin, & Doros, 2006). Results from other studies, however, indicate that intake is not consistent by the number of food units (Spiegel et al., 1993; Devitt & Mattes, 2004). The present study supports the latter findings in that subjects consumed a different number of pieces of the two types of snack (68 pieces of the less-aerated snack versus 24 pieces of the more-aerated snack). Thus, food properties other than the number of units influenced snack intake.

Snacking behavior has not been researched as extensively as eating behavior at meals. Since energy intake from snacks has been increasing in parallel with rising rates of obesity, strategies to minimize energy intake from energy-dense snacks merit further investigation. In addition, future studies should examine whether decreases in energy intake are observed with other foods that can be manipulated in air content and whether larger decreases in energy intake might be seen when the difference in air content is smaller and less noticeable. It will also be of interest to determine the effects of aeration on snack consumption over longer periods of time and in the presence of distractions such as watching television (Blass et al., 2006). Future studies should also assess whether adjustments in energy intake become more accurate with repeated consumption of foods differing in air content. There is evidence that energy compensation improves with repeated consumption of a snack; in one study, energy compensation at a subsequent meal improved after six exposures to snack foods varying in energy content (Louis-Sylvestre et al., 1989).

In conclusion, the results of this study indicate that, while varying the method of serving a snack did not influence energy intake, differences in the aeration of a snack did influence energy intake without affecting the magnitude of changes in ratings of hunger and fullness. The results of this study suggest that increasing the air content may be an effective strategy to reduce energy intake from energy-dense snacks.

Acknowledgements

This work was supported by the National Institutes of Health, grant DK059853 and grant DK039177.

References

Barkeling B, Linné Y, Melin E, Rooth P. Vision and eating behavior in obese subjects. Obesity Research 2003;11:130–134. [PubMed: 12529495]

Bell EA, Castellanos VH, Pelkman CL, Thorwart ML, Rolls BJ. Energy density of foods affects energy intake in normal-weight women. American Journal of Clinical Nutrition 1998;67:412–420. [PubMed: 9497184]

Bell EA, Roe LS, Rolls BJ. Sensory-specific satiety is affected more by volume than by energy content of a liquid food. Physiology & Behavior 2003;78:593–600. [PubMed: 12782213]

Bell EA, Rolls BJ. Energy density of foods affects energy intake across multiple levels of fat content in lean and obese women. American Journal of Clinical Nutrition 2001;73:1010–1018. [PubMed: 11382653]

Berteus Forslund H, Torgerson JS, Sjostrom L, Lindroos AK. Snacking frequency in relation to energy intake and food choices in obese men and women compared to a reference population. International Journal of Obesity (London) 2005;29:711–719.

Blass EM, Anderson DR, Kirkorian HL, Pempek TA, Price I, Koleini MF. On the road to obesity: Television viewing increases intake of high-density foods. Physiology & Behavior 2006;88:597–604. [PubMed: 16822530]

Devitt AA, Mattes RD. Effects of food unit size and energy density on intake in humans. Appetite 2004;42:213–20. [PubMed: 15010185]

Duncan KH, Bacon JA, Weinsier RL. The effects of high and low energy density diets on satiety, energy intake, and eating time of obese and nonobese subjects. American Journal of Clinical Nutrition 1983;37:763–767. [PubMed: 6303104]

Garner DM, Garfinkel PE. The eating attitudes test: An index of the symptoms of anorexia nervosa. Psychological Medicine 1979;9:273–280. [PubMed: 472072]

Geier AB, Rozin P, Doros G. Unit bias: A new heuristic that helps explain the effect of portion size on food intake. Psychological Science 2006;17 (6):521–525. [PubMed: 16771803]

Herman CP, Polivy J. Normative influences on food intake. Physiology & Behavior 2005;86:762–772. [PubMed: 16243366]

Koslowsky M, Scheinberg Z, Bleich A, Mark M, Apter A, Danon Y, Solomon Z. The factor structure and criterion validity of the short form of the Eating Attitudes Test. Journal of Personality Assessment 1992;58:27–35. [PubMed: 1545342]

Linné Y, Barkeling B, Rossner S, Rooth P. Vision and eating behavior. Obesity Research 2002;10:92–95. [PubMed: 11836454]

Louis-Sylvestre J, Tournier A, Verger P, Chabert M, Delorme B, Hossenlopp J. Learned caloric adjustment of human intake. Appetite 1989;12:95–103. [PubMed: 2764558]

Marmonier C, Chapelot D, Fantino M, Louis-Sylvestre J. Snacks consumed in a nonhungry state have poor satiating efficiency: influence of snack composition on substrate utilization and hunger. American Journal of Clinical Nutrition 2002;76:518–528. [PubMed: 12197994]

Marmonier C, Chapelot D, Louis-Sylvestre J. Metabolic and behavioral consequences of a snack consumed in a satiety state. American Journal of Clinical Nutrition 1999;70:854–866. [PubMed: 10539746]

Miller DL, Castellanos VH, Shide DJ, Peters JC, Rolls BJ. Effect of fat-free potato chips with and without nutrition labels on fat and energy intakes. American Journal of Clinical Nutrition 1998;68:282–290. [PubMed: 9701184]

Nielsen SJ, Popkin BM. Patterns and trends in food portion sizes, 1977–1998. Journal of the American Medical Association 2003;289:450–453. [PubMed: 12533124]

Nisbett RE. Determinants of food intake in obesity. Science 1968;159:1254–1255. [PubMed: 5711760]

Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. Journal of the American Medical Association 2006;295:1549–55. [PubMed: 16595758]

Rolls, BJ. Sensory-specific satiety and variety in the meal. In: Meiselman, HL., editor. Dimensions of the Meal: The Science, Culture, Business and Art of Eating. Gaithersburg, MD: Aspen Publishers, Inc; 2000. p. 107-116.

Rolls BJ, Andersen AE, Moran TH, McNelis AL, Baier HC, Fedoroff IC. Food intake, hunger and satiety after preloads in women with eating disorders. American Journal of Clinical Nutrition 1992;55:1093–1103. [PubMed: 1595580]

Rolls BJ, Bell EA, Waugh BA. Increasing the volume of a food by incorporating air affects satiety in men. American Journal of Clinical Nutrition 2000;72:361–368. [PubMed: 10919928]

Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. American Journal of Clinical Nutrition 2002;76:1207–1213. [PubMed: 12450884]

Shaw, J. The influence of the type of food and method of presentation on human eating behavior. Doctoral Dissertation; University of Pennsylvania, Philadelphia: 1973.

Spiegel TA, Kaplan JM, Tomassini A, Stellar E. Bite size, ingestion rate, and meal size in lean and obese women. Appetite 1993;21:131–45. [PubMed: 8285651]

Stubbs RJ, Harbron CG, Murgatroyd PR, Prentice AM. Covert manipulation of dietary fat and energy density: effect on substrate flux and food intake in men eating ad libitum. American Journal of Clinical Nutrition 1995a;62:316–329. [PubMed: 7625338]

Stubbs RJ, Harbron CG, Prentice AM. Covert manipulation of the dietary fat to carbohydrate ratio of isoenergetically dense diets: effect on food intake in feeding men ad libitum. International Journal of Obesity and Related Metabolic Disorders 1996;20:651–660. [PubMed: 8817359]

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Stubbs RJ, Ritz P, Coward WA, Prentice AM. Covert manipulation of the ratio of dietary fat to carbohydrate and energy density: effect on food intake and energy balance in free-living men eating ad libitum. American Journal of Clinical Nutrition 1995b;62:330–337. [PubMed: 7625339]

Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition, and hunger. Journal of Psychosomatic Research 1985;29:71–83. [PubMed: 3981480]

U.S. Department of Agriculture, Economic Research Service. USDA, Economic Research Service. Washington, D.C: 1999. America's Eating Habits: Changes and Consequences.

van Stratum P, Lussenburg RN, van Wezel LA, Vergroesen AJ, Cremer HD. The effect of dietary carbohydrate:fat ratio on energy intake by adult women. American Journal of Clinical Nutrition 1978;31:206–212. [PubMed: 623041]

Zizza C, Siega-Riz AM, Popkin BM. Significant increase in young adults' snacking between 1977–1978 and 1994–1996 represents a cause for concern! Preventive Medicine 2001;32:303–310. [PubMed: 11304090]

Zung, WWK. Zung self-rating depression scale and depression status inventory. In: Sartorius, N.; Ban, TA., editors. Assessment of depression. Berlin: Springer-Verlag; 1986. p. 221-231.

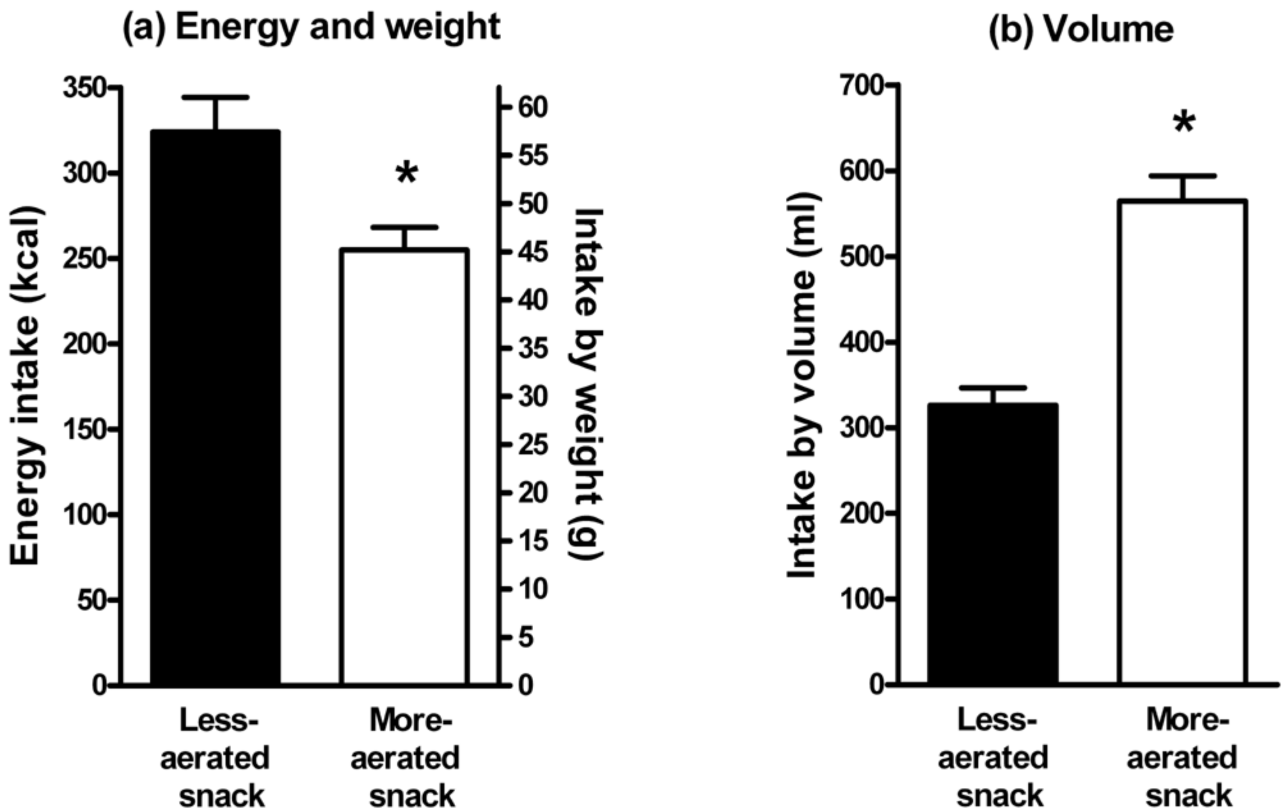

Figure 1.
Mean (± SEM) intake by (a) energy and weight and (b) volume of the less-aerated and more-aerated snacks in 28 subjects. Subjects consumed significantly less energy and weight and significantly more volume of the more-aerated snack than the less-aerated snack (* $p < 0.0003$). Since there were no interactions of snack type with snack serving method or subject sex, mean intakes across these factors are shown.

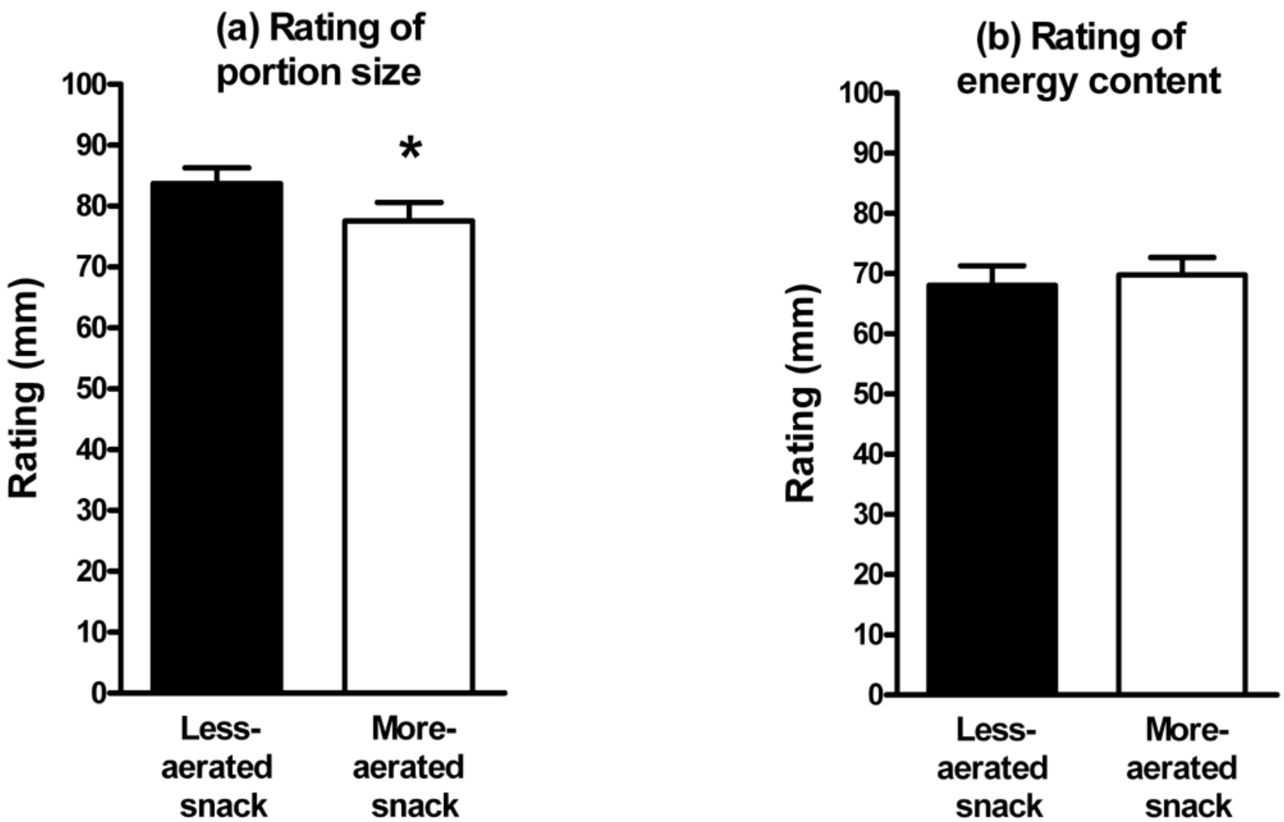

Figure 2.

Mean (± SEM) ratings of (a) portion size and (b) energy content of less-aerated and more-aerated snacks in 28 subjects. Mean ratings of portion size were significantly higher for the less-aerated snack (* $p = 0.003$), but mean ratings of energy content did not differ significantly by snack type. Ratings were assessed before consumption of the snack. Since there were no interactions of snack type with snack serving method or subject sex, mean ratings across these factors are shown.

Table 1

Characteristics of the two types of snack

Characteristic	Less-aerated snack[a]	More-aerated snack[b]
Weight served (g)	220	100
Energy served (kcal)	1256	571
Calculated volume served (ml)	1250	1250
Weight per volume (g/ml)	0.176	0.080
Energy density (kcal/g)	5.71	5.71
Energy per volume (kcal/ml)	1.00	0.45
Weight of one piece (g/piece)	0.84	1.85

[a]Cheetos Crunchy, Frito Lay, Inc., Plano, TX, USA

[b]Cheetos Puffs, Frito Lay, Inc., Plano, TX, USA

Table 2

Subject characteristics (mean ± SEM)

Characteristic	Women (n = 16)	Men (n = 12)
Age (y)	27.3 ± 2.2	26.8 ± 2.0
Weight (kg)	61.4 ± 1.9	76.2 ± 2.7[a]
Height (cm)	164 ± 1.2	179 ± 1.3[a]
BMI (kg/m^2)	22.8 ± 0.7	23.9 ± 0.9
Dietary restraint score[b]	8.8 ± 1.2	4.4 ± 0.6[a]
Disinhibition score[b]	5.1 ± 0.7	3.3 ± 0.5
Hunger score[b]	4.4 ± 0.7	4.4 ± 0.8
Depression score[c]	29.4 ± 1.1	27.9 ± 1.2
Eating attitudes score[d]	3.8 ± 0.9	4.3 ± 0.8

[a]Means are significantly different for men and women ($p < 0.004$).

[b]Eating Inventory (Stunkard & Messick, 1985; Koslowsky et al., 1992).

[c]Zung Self-rating Questionnaire (Zung, 1986).

[d]EAT-26 (Garner & Garfinkel, 1979).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 3

Snack intake by snack type, serving method, and subject sex (mean ± SEM)

Intake measure	Snack type	Women (n = 16) Serving method		Men (n = 12) Serving method	
		Bowl	Bag	Bowl	Bag
Weight (g)[1]	Less-aerated	52.7 ± 6.9	49.2 ± 7.5	61.1 ± 6.2	70.8 ± 7.2
	More-aerated	40.1 ± 3.1	37.7 ± 2.6	52.6 ± 5.6	54.4 ± 6.6
Energy (kcal)[1]	Less-aerated	301 ± 39	281 ± 43	349 ± 36	404 ± 41
	More-aerated	229 ± 18	215 ± 15	301 ± 32	311 ± 38
Volume (ml)[2]	Less-aerated	300 ± 39	279 ± 42	347 ± 35	402 ± 41
	More-aerated	501 ± 39	471 ± 32	658 ± 70	680 ± 82

[1] For the outcomes of snack weight and energy, there was a significant main effect of snack type (energy consumed was greater for the less-aerated snack; $p = 0.0003$) and subject sex (energy consumed was greater for men; $p = 0.034$). The effect of serving method and the interactions of these factors were not significant.

[2] For the outcome of snack volume, there was a significant main effect of snack type (volume consumed was greater for the more-aerated snack; $p < 0.0001$) and subject sex (volume consumed was greater for men; $p = 0.019$). The effect of serving method and the interactions of these factors were not significant.