Breakfast foods and satiety

Oatmeal provides a higher level of satiety than many other breakfast foods.
Satiety is related to a sense of fullness and loss of hunger. Measurement of satiety is a subjective process. Linear visual analog scales are used by many psychology and nutrition researchers to measure both feelings. A satiety index has also been developed, showing that foods provide different levels of satiety (see chart).

Delayed satiety contributes to overeating. On a physiological level, satiety inhibits ghrelin, a stomach hormone that increases hunger, and stimulates leptin, a hormone produced in adipose tissue believed to decrease appetite and increase energy expenditure.

Other biochemical regulators of food intake that decrease appetite/hunger are enterostatin in the pancreas and cholecystokinin, glucagon-like peptide 1, and peptide YY in the small intestine.

Satiety manipulation holds promise as a means to control obesity, despite numerous pitfalls. For example, people may continue to eat when full, particularly when engaged in another activity such as driving or watching television. Satiety effects may be short-lived, with no impact on daily energy consumption. Long-term compliance with satiating diet changes may falter, or the ability of the diet to produce satiation may decrease over time.

Finally, measurement techniques are very subjective, and numerous factors complicate the design of studies. For example, making experimental meals equal in calorie content may result in one meal being much smaller than another, adding a volume variable to the experiment.

Targeting Breakfast
Breakfast is an easy meal to miss in busy households. While cutting out one meal may appear to be a simple means to cut daily caloric intake, research indicates that this meal is the one not to be missed. Numerous studies have reported a link between breakfast skipping and obesity in children and adolescents. The National Weight Control Registry follows adults who have lost significant amounts of weight; 78% of successful dieters in the Registry reported eating breakfast every day (Wyatt et al., 2002). Even those individuals who eat breakfast may find that they feel hungry before lunchtime, thus breakfasts that delay stomach emptying may increase satiety and eventually allow consumers to control their energy consumption.

Can a stomach be fooled into feeling full? Expanding food volume with non-caloric ingredients, such as air and water, offers a means to limit energy intake. Before lunch, 28 lean men were given strawberry-flavored yogurt shakes whose volumes were...
altered by whipping in additional air (Rolls et al., 2000). The men were then allowed to consume foods the rest of the day *ad libitum*. Fullness was greater, and caloric consumption was 12% less, after the 600-mL shake was consumed, as compared with the 300-mL version.

Barbara Rolls, Professor of Nutritional Sciences at Pennsylvania State University, is the creator of the Volumetrics Eating Plan, and she has reported several other studies where increased volume led to increased feelings of fullness. Extruded breakfast cereals could be processed for greater expansion and lower bulk density; bakery products could likewise be processed to increase the size of the serving without increasing energy value. However, processing effects on digestibility should be evaluated before adopting such an approach.

When four types of white bread that were altered to have differing loaf volumes (1,100–3,000 mL) were fed to volunteers, the bread with the second lowest loaf volume had the highest satiety index (Burton and Lightowler, 2006). The densest bread provided the lowest glycemic index, but was disliked by volunteers.

Simply adding more water to a food can reduce calories while increasing volume. Several studies have compared non-breakfast foods with and without added water. In general, added water increased satiety, but did not necessarily reduce subsequent caloric intakes. While many breakfast foods do not lend themselves to dilution, cooked breakfast cereals such as oatmeal and grits could be suitably formulated to contain more water without viscosity loss.

Stomach responses to food are different in obese persons, who tend to have larger empty stomach volumes than do normal-weight people. A meal that may be satisfying to a person who is not overweight simply does not fill up a person with higher body mass index. Gastric emptying is faster in obese persons as well, contributing to feelings of hunger.

**Proteins**

Popular diet plans tout high protein intakes to control weight. Protein affects insulin activity and contributes to thermogenesis. However, both the amount and type of protein in a meal influence satiety. High-protein meals delay stomach emptying and thus create a longer-lasting feeling of fullness. After completion of a very-low-calorie diet for four weeks, overweight adults who consumed a 30-g protein supplement during weight maintenance tended to gain only fat-free mass and reported higher satiety compared to peers who did not receive the supplement (Lejeune et al., 2005). A high-protein breakfast was more effective than a high-carbohydrate breakfast in decreasing serum ghrelin levels after the meal (Blom et al., 2006).
Many breakfast foods are suitable for protein fortification. The Quaker Oats Co. markets three flavors of Quaker Weight Control instant oatmeal that contain 7 g of protein vs 4 g in its conventional instant oatmeal products, and 6 g vs 3 g of dietary fiber. Whey protein isolate provides the extra protein; oat flour and guar gum contribute soluble fiber. Dannon also markets a yogurt, Light & Fit Crave Control, with higher protein and dietary fiber content to curb appetite.

Breakfast is prime time for eggs. However, some consumers may not perceive eggs as a tool for weight control. To address this concern, a small study was funded by the Egg Nutrition Center. Thirty overweight women were given isocaloric, equal-weight breakfasts: 2 scrambled eggs, 2 slices of toast, and fruit spread were fed on one occasion, while a 3.5-inch bagel, 2 tablespoons of cream cheese, and 3 oz of nonfat yogurt were tested on a different day (Vander Wal et al., 2005). Protein, fat, and calories were slightly higher in the egg breakfast. Significantly more energy and macronutrients were consumed at lunch after the bagel breakfast. Perhaps the most intriguing finding was reduced energy intake for the 36 hr after the egg breakfast. Increased availability of frozen egg breakfast entrees, including some based on egg whites, may spur consumer acceptance of eggs for breakfast on busy mornings.

Lipids
Although lipids are the most energy-dense macronutrients, they are not necessarily the most satiating. Fats provide pleasant texture and flavor in the mouth that may retard satiety signals. Fat can delay stomach emptying, contributing to sustained feelings of fullness. Quantity, not fat source or degree of saturation, seems to play a more important role. When high-fat (6% of energy) test breakfasts differing only in ratios of polyunsaturated, monounsaturated, and trans fats were fed to young overweight men, no differences in postprandial appetite, amount of food consumed following the breakfast, or energy expended were observed (Flint et al., 2003).

A theory referred to as the ileal brake proposes that digestion of lipids in the ileum portion of the small intestine, rather than the duodenum (portion closer to the stomach), leads to a variety of changes that increase satiety and inhibit appetite. Thus, techniques to delay fat digestion could lead to satiety control. Such modifications have been explored in liquid-meal replacements that are popular on-the-go breakfast options.

Novel lipid emulsions added to these beverages were more slowly digested in vitro and subsequent feeding studies revealed that the modified drinks produced greater isocaloric satiety than did the original formula (Mela, 2006). Slim-Fast Optima shakes utilize this technology and contain an extra 1 g of lipid/serving. The company claims these products help control hunger for up to 4 hr. Critical to the development of ileal brake–stimulating foods will be the avoidance of steatorrhea that limits acceptance of orlistat and similar lipase inhibitors. Enteric-coated lipid supplements consumed with breakfast may offer another alternative.

Choosing a fat-free breakfast option may backfire because satiety may be reduced. Normal-weight young adults fed muffins containing comparable amounts of either peanut oil, canola oil, or butter, or a fat-free muffin reported greater hunger as little as 30 min after eating the fat-free muffin breakfast (Alfenas and Mattes, 2003). More calories were consumed at subsequent meals on the days that the volunteers ate the fat-free muffins as well.

Carbohydrates & Dietary Fiber
Now that the “low-carb” craze has passed, researchers are focusing on finding optimal types and amounts of carbohydrates for appetite control.
Simple sugars are rapidly digested and are targeted for reduction in some products. Although the application of glycemic index for food labeling is controversial, carbohydrate digestibility does appear to play a role in health. British schoolchildren consumed an average of 145 fewer calories at lunch after eating a low-glycemic-index breakfast (which included breakfast cereals), compared to high-glycemic-index breakfasts (Warren et al., 2003). This difference could not be attributed to simple sugars alone since the children consumed a mean intake of 119 calories more after eating the high-glycemic breakfast than they did after eating the low-glycemic breakfast with added sucrose.

What type of breakfast will be most satisfying? An Australian study (Holt et al., 1999) fed four types of experimental breakfasts to a small group of healthy young adults. The four meals were similar in energy content, although higher in calories than the volunteers’ typical breakfasts. A croissant breakfast represented a high-fat, high-carbohydrate meal; the egg and bacon breakfast was high in both fat and protein; a cornflakes option was high carbohydrate but low in dietary fiber; the high-bran cereal breakfast was high in both carbohydrates and dietary fiber. Volunteers felt the serving sizes of the high-fat options were too small. Perceived hunger was least and fullness highest after the high-bran breakfast but the cornflakes meal was more satisfying than the croissant breakfast. Alertness was higher after the high-bran breakfast, which took the longest to consume but was considered least appealing by volunteers unaccustomed to a high-bran cereal.

Dietary fiber encompasses many polymers whose physiological effects vary. Dietary fiber is not digestible, and despite partial fermentation of soluble fiber in the gut, these compounds can help dilute the energy density of foods. Soluble fiber increases the viscosity of intestinal contents that slows digestion and may decrease hunger. Insoluble fiber adds bulk and can speed a food’s transit time in the gastrointestinal tract. However, dietary fiber’s effect on satiety is not clear. Most foods contain a mixture of soluble and insoluble fiber that further complicates evaluation of satiation.

Dietary fiber helps maintain higher levels of cholecystokinin after eating. Since fat in foods spurs release of this hormone, California researchers compared breakfasts that varied in their fiber and fat content to assess effects of meal composition on satiety and related biochemical changes. The high-fiber, low-fat and low-fiber, high-fat breakfasts increased satiety in women, but not in men, who felt fuller after consuming either of the low-fat meals (Burton-Freeman et al., 2002). Plasma cholecystokinin concentrations were significantly associated with all subjective measures of satiety. The researchers concluded that for every 1% increase in plasma cholecystokinin, fullness ratings increased by 0.50 and hunger and desire to eat declined by 0.45.

Two options exist for using

Breakfast foods containing extra protein and fiber help provide a feeling of fullness. Examples are Quaker Oats Co.’s Quaker Weight Control instant oatmeal and Dannon’s Light & Fit Crave Control yogurt.
fibers to modulate satiety: direct addition to foods or use as a dietary supplement. Dairy-based beverages were fortified with 1% (by weight) of guar gum or two types of alginate, and their in vivo effects on satiety among volunteers’ stomachs were assessed by magnetic resonance imaging, MRI (Hoad et al., 2004). Alginates reacted with stomach acid to form lumps. Although gastric emptying was not significantly different among treatments, beverages containing guar and the 70% guluronic acid residue, high-gelling alginate increased fullness, despite being least palatable.

Bread fortified with wheat fiber affected serum levels of ghrelin and peptide YY after test meals compared to white bread or bread fortified with oat fiber, but all three bread types produced similar hunger ratings from volunteers (Weickert et al., 2006). Daily supplements of 8 g of oligofructose before breakfast and dinner for two weeks increased satiety after breakfast and dinner for two weeks and expanded feelings of fullness and alertness, despite higher calorie content per serving. Lighteners could be formulated to make these beverages more satiating. The roles of fatigue and lack of alertness in satiety should be explored further. Foods and beverages that maintain alertness may allow some consumers to avoid snacking for a “little extra” energy.

As indicated above, composition and physical properties of breakfast foods could be modified to increase satiety. Sensory quality of satiating foods requires careful balancing—not high enough and consumers will not use the product; too good and they may be tempted to consume larger portions than is desirable. Products to control appetite should be convenient for consumers, and shelf-stable, portable items may allow some consumers to avoid snacking for a “little extra” energy. Lighteners could be formulated to make these beverages more satiating. The roles of fatigue and lack of alertness in satiety should be explored further. Foods and beverages that maintain alertness may allow some consumers to avoid snacking for a “little extra” energy.

Increasing Satiety

Many Americans begin their day with coffee or tea. These beverages may be the only foods consumed for breakfast. Caffeine and related methylxanthines do exert some influence over appetite, but mechanisms for this effect have not yet been documented. Stimulants affect metabolism as well and thus may contribute to weight control. These beverages are clear and have negligible energy content until modified by the addition of sweeteners and dairy products. Opportunities exist to modify coffee and tea to increase their satiating ability while controlling caloric content per serving.

Bread fortified with wheat fiber affected serum levels of ghrelin and peptide YY after test meals compared to white bread or bread fortified with oat fiber, but all three bread types produced similar hunger ratings from volunteers (Weickert et al., 2006). Daily supplements of 8 g of oligofructose before breakfast and dinner for two weeks increased satiety after breakfast and dinner for two weeks and expanded feelings of fullness and alertness, despite higher calorie content per serving. Lighteners could be formulated to make these beverages more satiating. The roles of fatigue and lack of alertness in satiety should be explored further. Foods and beverages that maintain alertness may allow some consumers to avoid snacking for a “little extra” energy.

As indicated above, composition and physical properties of breakfast foods could be modified to increase satiety. Sensory quality of satiating foods requires careful balancing—not high enough and consumers will not use the product; too good and they may be tempted to consume larger portions than is desirable. Products to control appetite should be convenient for consumers, and shelf-stable, portable items may reach a greater share of our expanding population. FT

Mary Ellen Camire, Ph.D. (mary.camire@umit.maine.edu), a Professional Member of IFT, is Professor, and Megan Blackmore (megan.blackmore@umit.maine.edu) is Graduate Assistant and Dietetic Intern, Dept. of Food Science and Human Nutrition, University of Maine, 5735 Hitchner Hall, Orono, ME 04469-5735. Send reprint requests to author Camire.

REFERENCES