CFW RESEARCH

Measurement of Satiety of Wheat-Based Bulgur by Intervention and Sensory Evaluation

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ABSTRACT

Twenty-two healthy subjects consumed the following four test meals: Australian bulgur processed by boiling (boiled bulgur), Australian bulgur processed by steaming (steamed bulgur), Turkish bulgur, and high-amylose rice. Australian bulgur was made from durum wheat by using a traditional boiling and drying method and a method in which steaming replaced boiling. Meals were presented in a randomized order, one meal per test session at the same time and day of each week over four consecutive weeks. A within subject crossover design was used to investigate the satiety of bulgur in which each subject acted as their own control. Visual analogue scales were used to measure each subject's feelings of hunger and calculate rankings. Mean satiety index scores and area under the "How hungry do you feel right now?" curve values showed that the bulgur samples provided greater satiety than the high-amylose rice. Testing for differences in rank sums showed that bulgur (boiled and steamed) ranked significantly lower ($P < 0.05$) for hunger at 1 and 1.5 hr when compared with high-amylose rice. At 2.5 hr, bulgur (boiled) was ranked as significantly different to high-amylose rice ($P < 0.05$). Australian bulgur processed by boiling or steaming was more satiating than high-amylose rice.

Bulgur is a whole-grain food processed from wheat, preferably durum wheat, and is defined by Bayram (2) as cleaned, cooked, dried, and pulverized hard wheat.

Bulgur is a significant product in the Middle East and Turkey with more than 1,000,000 tons produced annually. It is well known for its satiety, but there is little or no scientific evidence to support this claim. The health benefits associated with whole-grain cereal consumption, such as the prevention of cancer, heart disease, and diabetes, are also likely to be observed following the consumption of bulgur. The measurement of satiety will provide results that will help define bulgur as a functional food.

Satiety refers to the state in which further eating is inhibited and occurs as a consequence of having eaten (8). Factors known to affect satiety include energy density, weight and volume, macronutrient composition, particle size, and palatability. Weight can affect satiety through differences in ingestion and digestion rates, gastric filling and emptying processes, and the subject's perception about size and associated feelings of fullness (17,23,24,28). Sensory properties can affect the subject's food choice and intake (5,12,21,29,33,34). Palatability can affect satiety, for example, it has been observed that highly palatable foods can stimulate a greater desire to eat and thus affect subsequent ratings of hunger (10,14).

Whole-grain foods provide high satiety (18,19,22,25,27,35), but studies into the level of satiety achieved from specific whole-grain foods are limited. The consumption of food that provides high satiety leads to feelings of fullness that is prolonged and may increase the time between eating occasions and reduce subsequent food intake (8,16). Therefore, a diet containing foods with high satiety such as bulgur, may allow individuals to control their energy intake without having to restrict their eating or endure high levels of hunger between meals.

A visual analogue scale (VAS) was used as a validated method for translating subjective sensations into a quantifiable objective measure to assess satiety (4,6,11). A VAS provides a tool for assessing the feeling of hunger and ranking foods in order of their ability to alleviate hunger over time. Sensory evaluation standard procedures (20,30) were followed where subjects also acted as panelists. Sensory evaluation also uses a VAS for assessing food characteristics such as texture or color or for measuring degree of liking (20). Panelists were seated in isolated sensory booths for test meal consumption, and test meals were presented according to the standard method.

The main purpose of this study was to determine if differences in satiety of similar whole-grain foods, three bulgur products processed in different ways and high-amylose rice, could be measured and if a significant difference in level of satiety existed between the different meals.

MATERIALS AND METHODS

The validated within subject repeated measures design and the VAS methods used by Holt and coworkers (15) and Barkeling and coworkers (1) were combined with sensory evaluation techniques to develop the following method.

Subject Selection

Healthy volunteers age 18 to 50 were recruited, screened by an interview, and they completed a subject selection questionnaire. The screening process enabled the selection of 21 healthy males and females with a body mass index (BMI) of 19–25 and one subject with a BMI of 26–29. Subjects were excluded if they smoked, were classified as restrained eaters by the questionnaire, if they had a medical or health condition, or were taking any prescriptive medication that would affect the purposes of the study. Subjects were excluded if they were currently on, or had been on, a weight-loss diet during the last

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6 months, if they were consuming less than three meals per day, if they found the food unacceptable, or had an allergy to any ingredient. Participants were asked to maintain their normal regular exercise. Subjects also completed a three-factor eating questionnaire, which was a tool used to evaluate a person's level of dietary restraint, disinhibition and perceived hunger (31), and suitability for sensory evaluation. Selected subjects had low dietary restraint (the tendency to limit food intake to control body weight) and disinhibition (the tendency to overindulge when food is readily available).

Test Food

The test food was made by methods developed during a 3-year project on bulgur processing and quality (9).

The Turkish bulgur sample was high-quality durum bulgur from Turkey. The Australian durum wheat bulgur samples were either steamed or boiled during the processing and all other processing steps were identical. The milled rice sample was a high-amylose Australian white rice variety, Doongara, which is marketed as having a lower glycemic index than most other rice.

No significant differences in energy content between the four samples were detected, and 170 g of the test foods contained 1,595 ± 125 kJ. The energy content of the bulgur samples was detected with a LECO-AC350 isoperibal calorimeter.

The test meal composition was standardized for all four test meals, with only the main carbohydrate component differing in each, either bulgur or rice. The three bulgur samples and the rice sample were prepared as low-fat, low-protein, and high-carbohydrate test meals. The bulgur and rice used in the test meals were cooked by a boiling and absorption method. The test meal was developed as a type of "hot breakfast" to address palatability. The meal consisted of 170 g of cooked bulgur or rice, plus 30 g of grilled eggplant, zucchini, tomato, and pine nuts in equal amounts. Subjects were also required to consume the 250 mL of water supplied with the meal.

Table I. Standard evening meal compositions for men and women[a]

Food Type Weight (g/serving)	No. of Servings for Men	Energy (kJ)	No. of Servings for Women	Energy (kJ)
Low fat frozen meal (370)	1	1,643	1	1,643
Diced natural fruit in juice (140)	2	682	1	341
Sports/breakfast bar (36.7)	2	1,140	1	570
White bread roll				
large = 90 g, small = 50 g	1 (large)	972	1 (small)	540
Polyunsaturated margarine (10)	1	18	1	18

[a] Total energy of the standard meal is 4,455 kJ for men and 3,122 kJ for women.

Table II. Visual analogue scale questions and end point anchors for each subjective sensation rated

Sensation	Question	Score 0	Score 10
Hunger	how hungry do you feel right now	not hungry at all	hungry as I have ever felt
Fullness	how full do you feel right now	not full at all	very full
Desire to eat	how strong is your desire to eat right now	very weak	very strong
Prospective consumption	how much food do you think you can eat right now	nothing at all	a large amount
Pleasantness	how pleasant did you find your food	not pleasant at all	very pleasant
Difficulty	how difficult was the meal to eat	not difficult at all	extremely difficult

Table III. Area under the curve (AUC) and satiety index score (SI)[a]

Test Food	Rank[b]	AUC (Mean)[c]	SI (Mean)
Boiled bulgur	1	1101.20 a	88.34
Steamed bulgur	2	1181.52 a	94.51
Turkish bulgur	3	1201.33 a	96.37
Rice	4	1276.40 a	100[d]

[a] AUC = 30 min to before lunch and SI = response to question "How hungry do you feel right now?"
[b] Highest hunger = 4 and lowest hunger = 1.
[c] Values followed by same letters are not significantly different. Highest hunger = 4 and lowest hunger = 1.
[d] Reference food.

Procedure

Factors that influence satiety and are related to the test meal, including energy density, weight and volume, macronutrient composition, particle size, and palatability, were all controlled in the study.

A within subject crossover design was used in which subjects acted as their own control. They were required to attend one test session per week at the same time and day of each week for four consecutive weeks, under as similar conditions as possible (15,21,26). Each subject consumed all four test meals in random order, one different meal each week.

The day before the test day, subjects were asked to eat an evening meal that consisted of a frozen meal standardized at 4,455 kJ for men and 3,112 kJ for women. Subjects were instructed to eat the evening meal (Table I) as close to 7pm as possible and then fast for 10 hr, consuming only water. On the morning of the test, subjects reported to the taste panel room, were placed in individual booths, and given the test meal.

Subjects were required to complete a VAS, rating their feelings of satiety before consuming the test meal. A 100-mm VAS was used for each sensation (Fig. 1).

Subjects consumed their test meal and then completed the VAS, rating their feelings of fullness, desire to eat, prospective consumption, the pleasantness, and the difficulty in eating the meal (Table II).

Subjects were asked to complete one VAS every 30 min, and the completed sheet was placed in the envelope provided before reading and completing the next line scale. This methodology was used to reduce the chance of subjects referring to their previous ratings. After eating the test meal, subjects selected their lunch from a menu provided. Individual lunches, including all food items, were weighed and described and the data was used to confirm that the subjects were healthy eaters. Details of the type and amount of food and drink consumed by subjects were recorded on the lunch menus by the researcher.

Statistical Analysis

Rank sum sensory analysis (30), satiety index (14), and satiety response curve (area under the curve) methods (15) were used to analyze results.

Rankings for each individual at specific times after eating were calculated from the visual analogue records and were added to achieve a rank sum. *F* values were calculated for the 22 panelists rank sum and a critical value calculated. A significant difference existed if the difference in rank sum was greater than the critical value.

The total area under the curve was calculated for each individual subject from his or her hunger and fullness response curves, each treated separately. The satiety response to a food was quantified as the total area under the curve from just after the test meal and 0–4 hr after eating the test meal, calculated using the trapezoidal rule (7). Satiety index scores were calculated for each individual subject for hunger and fullness and for each of the four test foods.

The satiety index scores were then obtained by dividing the area under the "How hungry do you feel right now?" curve for the test food, the bulgur samples, by the area under the curve for the reference food (high-amylose rice) and expressed as a percentage with rice 100%. Holt and coworkers (14) measured fullness to develop a score, which was related to white bread (100%).

One-way analysis of variance was used to determine if there were any significant differences between the area under the curve values and satiety index scores.

RESULTS AND DISCUSSION

The energy density range (1,470–1,722 kJ/100 g) and particle size (half to whole-grain size) of the four test meals were similar, and the differences were considered insignificant within the context of this project. The use of a standard weight of the test meal (170 g) meant that weight and volume effects on satiety were controlled.

Panelists may be influenced by the test meal weight or volume, palatability, and texture including particle size. They rated the difficulty to eat the test meal as not to be significantly different between the four meals and rated low in difficulty to consume. The pleasantness ratings for the test meals (7.08–7.36 on a 0–10 VAS) were determined not to be significantly different from each other, and overall, the subjects stated that the meals were pleasant to consume.

Weight or volume, palatability, and texture are not controlled in most satiety studies because of the range of food types usually tested (16). However, subjects in this study were unable to tell whether they were eating bulgur or rice test meals because of the similar appearance, color, taste, and texture of the meal.

Ranking of meals for hunger at a specific time after consumption were calculated according to Standards Australia, sensory examination of foods (AS 2542.2.6 1995).

The 22 panelists' rankings of the four meals (highest hunger rank was given a value of 4 and the least hunger given a value of 1) were totaled to obtain a rank sum. If the rank sum difference between the meals was greater or equal to a critical value of 16.85, then there is a significant difference between the meals for satiety.

Holt and Brand-Miller (13) chose to measure satiety on the basis of measuring when hunger returns, after the consumption of high-water foods, and from this measurement they made a prediction of the degree of fullness at 2 hr after eating. High-satiety food would be expected to delay hunger for as long as possible. In the current study, satiety was measured every 30 min and up to 4 hr after the test meal was consumed on a VAS (Fig. 1). Meaningful measurements could be made if a standard time within 1–2.5 hr range was used (Fig. 2).

Rank sum for the steamed and boiled bulgur were significantly different to rice for hunger at 1 and 1.5 hr after eating. At 2.5 hr, boiled bulgur was significantly different to rice (critical value greater than 16.75), however, steamed bulgur, while still having the second lowest hunger ranking, differed from rice by a value of 15. At 4 hr, all bulgur meals ranked lower than the rice meal, and at the "before lunch" period, boiled bulgur ranked the lowest but was not significantly different to rice (critical value of 15).

The 22 subjects were significantly less hungry after consuming boiled bulgur rather than the other bulgur meals or rice for at least 2.5 hr. The possible reason boiled bulgur provides greater satiety may be because the more soluble starch leaches during boiling, leaving bulgur that is higher in protein and with possibly higher resistant starch, as a percent of the whole grain. The bulgur quality project (20) showed that leached solids can range from 1 mg/g of the original grain to 7 mg/g with increased boiling time to 30 min, depending on the original grain size and hardness.

Differences in the mean satiety index scores and area under the curve values for the "30 min" to "before lunch time" frame (Table III) indicated that the bulgur samples provided greater satiety than that for high-amylose rice.

The ranking for area under the curve over 4 hr and satiety index visual analogue question "How hungry do you feel right now?" resulted in a "least hungry" to "most hungry" rank of boiled bulgur, steamed bulgur, Turkish bulgur and rice, respectively.

The ranking for "How full do you feel right now?" resulted in a "most full" to "least full" rank for boiled bulgur, steamed bulgur, Turkish bulgur, and rice, respectively.

VAS results of the 22 subjects were combined, and the mean scores for rating

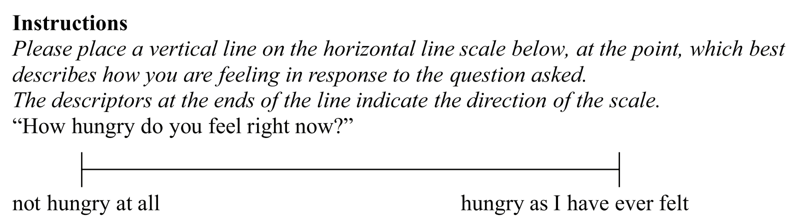

Fig. 1. Visual analogue scale for question, "How hungry do you feel right now?"

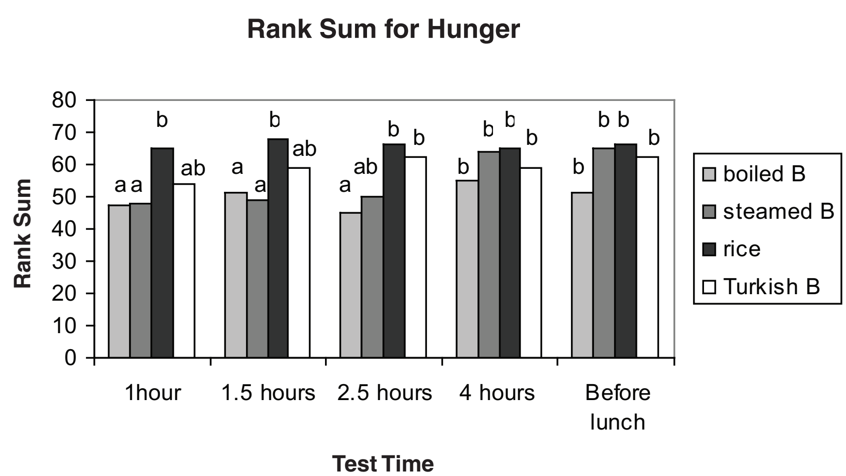

Fig. 2. Rank sum of 22 subjects for the ranking of "How hungry do you feel right now?" Rank sums that do not have a common superscript are significantly different at $P < 0.05$.

feelings of hunger compared the satiating effect from boiled bulgur and high-amylose rice. Boiled bulgur rated lower than did rice for hunger from 1.5 hr until the recorded "before lunch" rating (Fig. 3).

In this study, the factors known to affect satiety, the physical characteristics of the bulgur and rice, such as energy density, weight and volume, macronutrient composition, particle size, and palatability, were controlled. Other factors that may be contributing to satiety differences of the whole-grain bulgur and rice may be glycemic index (GI), fiber, and resistant starch. The research samples selected and processed for this study addressed the GI, fiber, and resistant starch issues.

Holt and coworkers (15) found that the GI of bread did not impact the fullness response, but whole-grain foods may not show the same response as bread. In contrast, Read and Kouris-Blazos (24) report that low glycemic index food may delay the return of hunger, and therefore, influence satiety. Tetens and Rice (32) also found high-amylose rice was potentially more satisfying than low-amylose rice.

Bulgur is in the low GI range of less than 55. High-amylose rice, Doongara, was selected as the reference food because it has a "lower" GI of 56 when compared with other rice (in Australia, to be labeled "low" GI, a food must be less than 55). High-amylose rice was chosen because it has a lower GI than other white rice, and therefore, would be closer to the test food. Dietary fiber is known to positively affect satiety, and bulgur is also known to have greater dietary fiber content than the high-amylose rice. In terms of diet, fiber and resistant starch are related. Resistant starch type 1 or physically inaccessible starch because of entrapment in the plant tissue matrix may be a factor for bulgur as a whole-grain product. Starch that undergoes a gelatinization and retrogradation process, as described by BeMiller and Whistler (3), is known as resistant starch type 3 and is present in rice and bulgur but at very low levels, approximately 1%, so it should not have a significant influence.

CONCLUSIONS

There was no significant difference in difficulty, time taken to eat, and pleasantness of the different test meals made from bulgur or rice. This confirmed that palatability was effectively standardized for all test meals. This study has found differences in satiety, partly because of the control of density, particle sizes, and palatability of the test food. The "area under the curve" technique for testing equal portions of bulgur and rice gave consistent trends and bulgur rated lower than rice for hunger from 1.5 hr until the recorded before lunch, but the difference was not significant. Differences in the mean satiety index scores and area under the curve values suggest that the bulgur provided greater satiety than that of the rice.

The uniqueness and significance of this research is the combination of sensory evaluation techniques and ranking food for the characteristics tested. Significant satiety differences were obtained in meals from very similar grain. The difference in bulgur because of processing was able to be measured and different whole grains, i.e., rice meal and wheat-based bulgur meal, showed significant differences for satiety. Bulgur when boiled or steamed during processing gave significantly higher satiety or lower rank sum for hunger than the rice at 1 and 1.5 hr. Bulgur, when boiled during processing, gave significantly higher satiety at 2.5 hr than the rice.

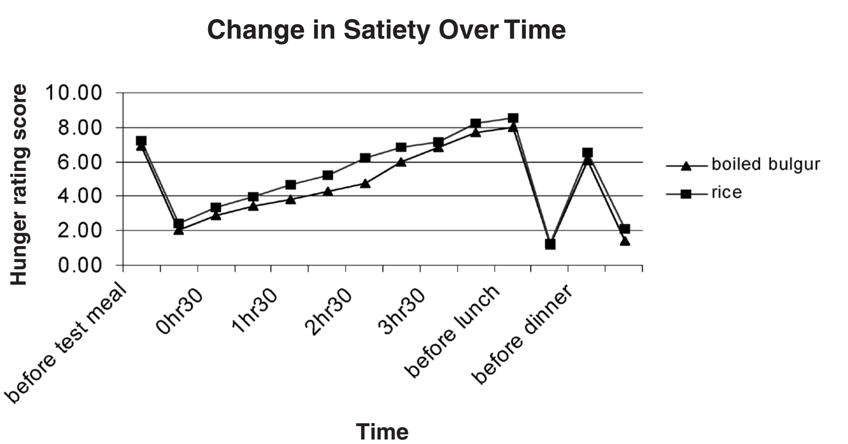

Fig. 3. Mean satiety rating score of 22 subjects over time for boiled bulgur and rice meals for the question "How hungry do you feel right now?"

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