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Research Article

Effect of Oak Flour on Glycemic Index and Satiety Index of White Bread

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Abstract

Background: Low Glycemic Index (GI) and high Satiety Index (SI) foods have been associated with the decreased risk of chronic diseases and obesity.
Objectives: The present study examined the effect of oak flour on GI, Glycemic Load (GL), and SI of white bread.
Methods: This randomized crossover trial was conducted at Ahvaz University of Medical Sciences, Ahvaz, Iran, during the year 2017. To determine the GI, 10 healthy subjects consumed three bread types (white bread, bread containing 25% oak flour, and bread containing 50% oak flour) and reference food (glucose) containing 50 g of carbohydrates on separate occasions. Finger-prick blood samples were collected at fasting (0 min) and at 15, 30, 45, 60, 90, and 120 min after meal consumption. To determine the SI, 20 healthy individuals consumed 240 kcal portions of test bread types (white bread, bread containing 25% oak flour, and bread containing 50% oak flour) on separate occasions. The satiety ratings were collected at fasting and every 15 min for over 2 h after food ingestion to evaluate the SI.
Results: There were no significant differences in the mean of blood glucose Incremental Areas Under the Curve (IAUC) between the test bread types (white bread: 2,883.2 ± 353.7 vs. 25% oak flour bread: 3,163.1 ± 214.7 vs. 50% oak flour bread: 3,245.1 ± 255.9) ($P > 0.05$). Also, no significant differences were observed between the mean of bread GIs ($P > 0.05$). The satiety IAUCs of both oak bread types (25% oak flour bread: 377.17 ± 59.83, 50% oak flour bread: 427.87 ± 55.46) were significantly greater than that of white bread (248.55 ± 46.45) ($P < 0.001$). The SI of both oak bread samples (25% oak flour bread: 202.48 ± 7.92, 50% oak flour bread: 266.25 ± 11.66) was significantly greater than that of white bread (100) ($P < 0.001$).
Conclusions: The addition of oak flour did not modify the GI; however, it increased the SI of white bread and created a greater feeling of satiety.

Keywords: Bread, Glycemic Index, Quercus, Satiety Index

1. Background

Foods containing carbohydrate have different effects on blood glucose, depending on the nature of the food, as well as the type and amount of carbohydrates. This difference in blood glucose concentration is determined by the Glycemic Index (GI) (1). Food with low-GI has beneficial effects on postprandial plasma glucose (2). Epidemiological studies have shown that the consumption of low GI food is associated with the reduced risk of chronic diseases such as diabetes, cardiovascular disease, and obesity (3). Thus, finding low-GI food can improve chronic diseases. Furthermore, it has been reported that low-GI food is associated with more satiety (4). The Satiety Index (SI) is an indicator that expresses the sensation of satiety after eating food. High-SI food usually produces more satiety and reduces food intake (5). Considering the prevalence of obesity, finding food that generates more satiety sensation may be useful in the treatment and prevention of obesity.

White bread is one of the world's most consumed staple food products. However, white bread has a high glycemic index and is, therefore, restricted to the diabetic diet (6). Adding substances such as fibers and cereal flour to white bread can reduce its GI and enhance its SI (7-9).

Oak kernels (Oak kernel spp.) are mainly composed of starch, proteins, oils, fibers, minerals, vitamins, and significant amounts of antioxidant properties (10, 11). The beneficial effects of oak and its extracts on reducing blood glucose have been shown in some studies (12-15).

2. Objectives

The effect of oak flour on GI and SI of white bread has not been investigated so far. In this study, therefore, the effect of oak flour was examined on GI, Glycemic Load (GL), and SI of white bread.

3. Methods

This randomized crossover trial was conducted at the Department of Nutrition, Faculty of Paramedical Sciences, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran, during the year 2017. All participants were recruited through recall among the students of Ahvaz Jundishapur University of Medical Sciences. Informed consent was taken from all individuals before inclusion in the study. The registration ID was IRCT20180201038584N1 in the Iranian Registry of Clinical Trials.

3.1. Test Meals

Three types of bread were investigated in this study, including bread made of 100% white wheat flour, bread made of 50% white wheat flour and 50% oak flour, and bread made of 75% white wheat flour and 25% oak flour.

Oak fruit (*Quercus brantii*) was purchased from a local market in Yasuj, Kohgiluyeh and Boyer-Ahmad Province, Iran. Oak kernels were ground into flour and mixed with white wheat flour in different portions (25% and 50%).

Preparation of dough: We used 300 ml water, 8 g salt, 16 g yeast, and 0.3 g improver for each 500 g flour. After mixing the ingredients for 15 min, the dough was proofed (at 24°C) for 30 min and then moderately degassed by pressing the dough out, followed by resting at room temperature for 60 min. It was eventually baked at 250°C for 6 min. Afterward, each type of bread was cooled for 2 h, packed in polyethylene bags, and stored in a freezer until test day. The compositions of bread samples are presented in Table 1.

Table 1. Chemical Composition of Test Bread Types (g/100 g)

Components	White Bread	Bread with 25% Oak Flour	Bread with 50% Oak Flour
Protein	7.47	6.56	5.64
Fiber	1.9	3.3	4.8
Fat	0.77	1.31	2.91
Moisture	30	34.25	33.25
Ash	1.11	1.23	1.33
Available carbohydrate	58.74	53.34	52.05

Test bread palatability was assessed using a seven-point hedonic scale with seven options, including very bad taste, a little bad taste, bad taste, tasteless, slightly delicious, delicious, and very delicious.

3.2. Glycemic Index

Based on standard methods (16), 10 healthy individuals (eight women and two men; age 24.1 (SD 2.7) years; BMI 22.4 (SD 1.7) kg/m^2) participated in this study. The inclusion criteria were as follows: age 20 - 40 years, fasting blood glucose < 110 mg/dL, BMI in the normal range (18.5 - 24.9 kg/m^2), and following the usual diet. The exclusion criteria were pregnancy, lactation, smoking, metabolic diseases or gastrointestinal disorders, and taking medications that might affect glucose metabolism.

3.2.1. Glycemic Index Study Design

Subjects were studied on four different occasions, separated by approximately seven days in random order. Subjects consumed the same meal type for dinner on the night before each test day. In addition, subjects were asked to refrain from any intense physical activity 24 h before study days.

In each study day, they were referred to the study lab after a 10 - 12 h overnight fast and a fasting finger-prick blood sample was taken (time 0) using a calibrated glucometer (Accu-Chek® ACCU-CHEK Performa-Germany). Thereafter, the subjects consumed the test bread or glucose solution containing 50 g of available carbohydrate. The next blood samples were taken at 15, 30, 45, 60, 90 and 120 min after the start of the meal. Subjects were not allowed to eat or drink for 2 h (16). All test bread samples were served with 200 mL of water. One serving of anhydrous glucose powder dissolved in 200 mL water was used as the reference food.

The Incremental Area Under the Curve (IAUC) was calculated using a trapezoidal formula (17) and the GI and GL were calculated using the following formulas.

$$GI = (\text{IAUC test bread}/\text{IAUC reference food}) \times 100$$

$$GL = GI \times \text{Available Carbs (g)}/100$$

To calibrate the glucometer, the blood glucose of 90 serum samples was measured by an automatic analyzer (BT3000, Biotecnica, Italy) and a significant correlation was obtained ($r = 0.965$, $P < 0.0001$).

3.3. Satiety Index

Based on the standard methodology for determining the satiety index (18), 20 healthy individuals meeting eligibility criteria participated in this study. Subjects had a mean (± SD) age of 23.25 ± 2.7 years, mean BMI of 25.7 ± 16.17 kg/m^2, and mean fasting blood glucose of 88.48 ± 18.63 mg/100 mL. The inclusion criteria were an age of 20 - 40 years and weight in the normal range. The exclusion criteria were taking any medication that might affect gastric emptying, weight, and appetite, in addition to the criteria for entering the GI test.

3.3.1. Satiety Index Study Design

Subjects were studied on three different occasions, separated by approximately seven days. On each day of the study, they were referred to the study lab after an overnight fast (10 - 12 h) and their fasting blood glucose concentrations were measured with a glucometer. Before ingestion of the test meals, their subjective feeling of satiety was assessed using a 100 mm VAS that is used to measure qualitative variables. The subjects immediately ingested the tested bread (240 kcal) with 220 mL of water within 15 min. Another VAS was also completed for the palatability of bread. Subsequently, the participants were instructed to report their satiety feelings every 15 min for 120 min, during which the subjects were not allowed to eat or drink anything (18).

The IAUC of satiety was calculated with the trapezoidal formula (17), ignoring the area beneath the baseline. In addition, the satiety index was calculated using the following formula:

$$SI = (\text{IAUC of test bread}/\text{IAUC of white bread}) \times 100$$

3.4. Statistical Analyses

The results are expressed as mean ± SEM. All data were statistically analyzed using Microsoft Excel Spread Sheets and the Statistical Package for Social Sciences (SPSS, version 24). Repeated-measures ANOVA was used to assess significant differences in blood glucose, satiety responses, and IAUCs between the test meals. A P value of < 0.05 was considered significant.

4. Results

4.1. Glycemic Index

All participants completed the study. The mean postprandial changes in plasma glucose after the consumption of each test meal are shown in Figure 1. The mean blood glucose levels at 15 and 30 min were significantly different for all bread samples ($P < 0.05$). However, no significant differences were found between postprandial blood glucose responses to bread samples. Although white bread had lower IAUC than oak bread samples, there were no significant differences between the three bread samples (Table 2 and Figure 2). The mean GI of white bread was lower than that of oak bread (Table 2). However, there were no significant differences between the GL of the bread samples ($P > 0.05$).

4.2. Satiety Index

All participants completed the study protocol. As shown in Figure 3, a significant difference was observed between the satiety responses to the test bread samples ($P < 0.001$). Table 3 and Figure 4 show the satiety IAUC after ingestion of test bread. The satiety IAUC of oak bread samples was significantly greater than that of white bread ($P < 0.001$). There were no significant differences between the satiety IAUC of oak bread ($P = 0.099$).

The mean SI (± standard error) of the three test bread samples is shown in Table 3. White bread was used as the reference food. There was a significant difference between the SI of test bread samples ($P < 0.001$). There was a greater SI for bread with 50% oak flour than for bread with 25% oak flour ($P = 0.014$).

No adverse events were reported during the study. The palatability ratings (mean ± SEM) of white bread, bread with 25% oak flour, and bread with 50% oak flour were 1.57 ± 0.21, -0.08 ± 0.27, and -0.71 ± 0.33, respectively. Mean palatability rating was higher for white bread than for both oak bread samples; thus, white bread was significantly more palatable than both oak bread samples ($P < 0.001$). There were no significant differences between the palatability of oak bread samples ($P = 0.085$).

5. Discussion

In the present study, we investigated the effects of adding oak flour on GI, GL, and SI of white bread as high-GI food. The results of the study revealed that the addition of oak flour had no significant effects on the GI and GL; however, it significantly increased the satiety index of white bread.

In the current study, the GI was similar for all bread types indicating that oak flour had no significant impact on the GI of white bread. One of the main strategies for reducing post-meal glucose response and GI of foods is to increase the dietary fiber intake (19). In this study, oak flour increased fiber content, yet contrary to our expectations, the GI of white bread was not reduced. Moreover, the particle size of flour used in food preparation, dietary components such as moisture and protein content, and food processing methods are other factors that can contribute to

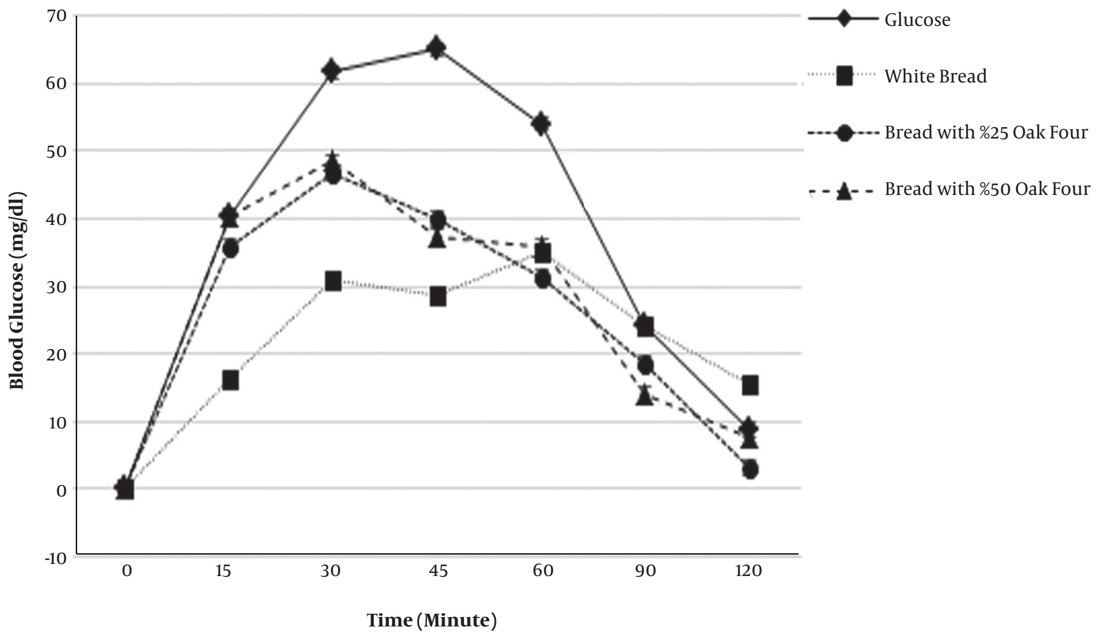

Figure 1. Blood glucose responses after ingestion of 50 g of available carbohydrate from glucose, white bread, bread with %25 oak flour and bread with %50 oak flour

Table 2. The Mean ± SEM of Blood Glucose IAUC, Glycemic Index, and Glycemic Load After Consumption of Glucose and Test Bread Types

Parameters	Glucose	White Bread	Bread with 25% Oak Flour	Bread with 50% Oak Flour
IAUC	4621.4 ± 413.7	2883.2 ± 353.7	3163.1 ± 214.7	3245.1 ± 255.9
Glycemic index	100	73.17 ± 18.23	75.88 ± 11.92	77.3 ± 11.91
Glycemic load	100	12.89 ± 3.21	12.14 ± 1.90	12.07 ± 1.85

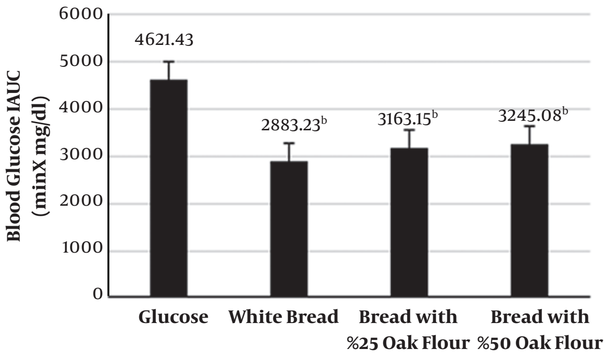

Figure 2. The blood glucose Area Under the Curves (AUC) (mean ± SEM) for glucose and test bread types. Different letters indicate significant differences between glucose and test bread types (P < 0.001).

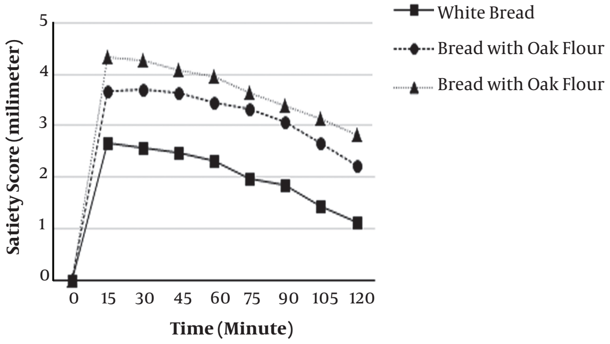

Figure 3. Satiety response curves for white bread, bread with %25 oak flour and bread with %50 oak flour. Data are mean ± SEM.

the GI of food (20, 21). Despite the benefits of fiber in relation to gastrointestinal function, data have been inconsistent to support the benefits of glycemic response. In some studies, the consumption of fiber-rich food has shown to lower glucose responses (22, 23) and GIs of tested food (22, 24). In contrast, no significant effect of fiber on postprandial glucose and GI value has been reported in other stud-

Table 3. The Mean ± SEM of Satiety IAUC and Satiety Index After Consumption of Test Bread Types[a]

Parameters	White Bread	Bread with 25% Oak Flour	Bread with 50% Oak Flour
IAUC	248.55 ± 46.45[A]	377.17 ± 59.83[B]	427.87 ± 55.46[B]
Satiety index	100	202.48 ± 7.92[A]	266.25 ± 11.66[B]

[a] Different letters indicate significant differences ($P < 0.001$).

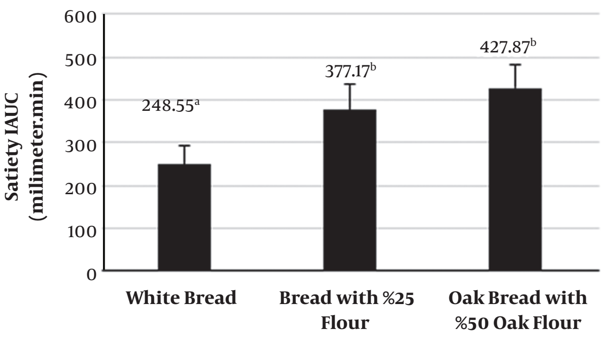

Figure 4. The satiety Area Under the Curve (AUC) (mean ± SEM) after the ingestion of test bread types. Different letters indicate significant differences ($P < 0.001$).

ies (25, 26). Further studies are warranted in this regard.

The important finding of this study was a significant increase in the SI of white bread. The SI of oak bread was found to be more than twice that of white bread. It has been reported that dietary fiber can induce satiety and provide a feeling of fullness (18, 27). Thus, the higher fiber content may be responsible for increasing the satiety effects of oak bread. Exerting short-term satiety can be due to delayed gastric emptying, altering the viscosity of gastric alimentary bolus (28). There is some evidence that in addition to fiber content, large particle sizes might enhance satiety more than small particle sizes (29). It has also been reported that refined-grain food compared with wholegrain food has often fewer particle sizes (30, 31). Since oak kernels (oak semen) can be considered a whole grain and the particle size of oak flour is larger than that of white flour, the addition of oak flour to wheat flour can increase its particle size, possibly increasing the satiety rating after consumption of oak bread. Moreover, high contents of tannins and phenolic compounds in oak flour may contribute to its satiety-induced effect. The administration of plant-derived phenolic compounds has shown to induce satiety and implicated in appetite regulation mechanisms (32, 33). It has been shown that phenolic compounds can affect the satiety sensation by several mechanisms including modulating the secretion of the gastric inhibitory polypeptide, glucagon-like peptide-1 (34), ghrelin (35, 36), and leptin (37). In addition, tannins can reduce starch digestibility by interacting with carbohydrate-hydrolyzing enzymes (α-amylase and glucoamylase), which, in turn, increase satiety by modulating depletion after the ingestion of carbohydrate-rich meals (38, 39). It has been indicated that Gallic acid found in oak bark can limit the food intake by inhibiting intestinal dipeptidyl peptidase-4 (DPP4) activity, consequently increasing GLP-1 production and increasing satiety.

To the best of our knowledge, the present study is the first study examining the effect of oak flour on the GL and SI of white bread. However, the limitations of the current study were the lack of the measurement of biochemical indices (insulin, GIP, and GLP-1) involved in blood glucose and appetite regulation and the lack of examination of food intake after 120 min that could provide a more complete interpretation of the results.

5.1. Conclusions

According to our findings, the addition of oak flour did not modify the GI of white bread. However, the addition of oak flour increased the satiety response of white bread. These results suggest that bread products containing oak flour, presenting a high SI, may be beneficial for the treatment and prevention of obesity. Further studies are warranted to improve its palatability.

Footnotes

Authors' Contribution: Zahra Salimi: Designed and performed experiments and co-wrote the paper. Farideh Shishehbor: Designed and supervised the research and co-wrote the paper. Masood Veissi: Designed and performed experiments. Amal Saki Malehi: Analyzed data. Mahdi Shiri-Nasab: Performed lab work. Bizhan Helli: Project advisor.

Clinical Trial Registration Code: Registration ID in the Iranian Registry of Clinical Trial is IRCT20180201038584N1.

Conflict of Interests: The authors have no conflicts of interest to declare.

Ethical Approval: The protocol was approved by the Ethics Committee of the Ahvaz Jundishapur University of Medical Sciences (code number: IR.AJUMS.REC.1396.870).

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