BIOAg Project Report

Report Type: Progress

Title: Human Health from Soil to Society: Barley β-glucan, glycemic control, and appetite

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Abstract:
Interest in barley (Hordeum vulgare L.) as a functional food for human consumption is increasing due to its high content of β-glucan, a soluble fiber. β-glucan can improve glycemic control, as gel formation in the intestine can reduce digestibility of starches and glucose uptake, elicit gastric distension, increase fecal transit time, and reduce appetite and food intake. WSU released two new spring barley varieties, 'Meg's Song' (8% β-glucan) and 'Havener' (7% β-glucan). These varieties are approximately 80-100% higher in β-glucan than commonly grown barley varieties. Barley varieties in the commercial marketplace contain levels of β-glucan as high as 10-12% ('Sustagrain'). We are conducting a randomized, controlled, crossover study in approximately 30 volunteers to determine the effects of high vs. medium vs. low β-glucan on short-term glycemic control and appetite in healthy humans. Participants consume a wholegrain breakfast porridge made of either high β-glucan barley (HB; 10% β-glucan), medium β-glucan barley (MB; 8% β-glucan), low β-glucan barley (LB; 7% β-glucan), or white glutinous rice (WR; 0% β-glucan), standardized for volume and energy content. Directly prior to the porridge preload and every 15 minutes thereafter, measurements of blood glucose are collected and participants rate subjective appetite using a computerized 100-mm Visual Analog Scale (VAS). After a total of 17 serial measurements over 4 hours, participants consume an ad libitum test meal. Within-subjects analyses will be used to assess differences in blood glucose, subjective appetite, and test meal consumption between conditions varying in β-glucan content. Study findings will contribute to the growing body of evidence linking barley β-glucan and positive health outcomes.

Project Description:
We are evaluating the effects of β-glucan barley on short -term glycemic control and appetite. To achieve our specific aims, we conducted a randomized cross-over human clinical trial. Each participant served as their own control, reducing both variation and required sample size.

This trial is a total of 8 study sessions. Participants could end the trial early, after 4 study sessions, if they determine the time commitment is too much. Participants could also join the trial late, joining for the remaining 4 study sessions. This allowed the researchers to obtain useable data from the first four visits, the full 8 visits, or the final 4 visits.

Participants visited Dr. Perrigue's Food Lab for a 4.75-hour testing session. Participants arrived at 7:45 am after an overnight (10-12 hr.) fast. At baseline (8:00 am) and every 15 minutes thereafter, participants completed appetite ratings using computerized Visual Analogue Scales (VAS) and tested their own blood glucose by using a finger prick and glucometer. A total of 17 finger pricks were collected every 15 minutes between 8:00 am and 12:00 pm. At 8:00 am, directly after the first appetite rating and blood glucose measurement, participants consumed a barley porridge that may or may not have included corn syrup.

Participants that completed the first four weeks of the trial consumed one of four equal-volume products varied in β-glucan content: a) low β-glucan barley, b) medium β-glucan barley, c) high β-glucan barley, and d) glutinous white rice (no β-glucan). Participants that continued for an additional four

weeks, or were recruited after former participants dropped out, consumed one of four equal-volume products varied in β-glucan content and sugar: a) low β-glucan barley sweetened with corn syrup, b) medium β- glucan barley sweetened with corn syrup, c) high β-glucan barley sweetened with corn syrup, and d) glutinous white rice sweetened with corn syrup.

Each preload provided approximately 1.5 cups of food and 250 calories. Participants were provided with 12 fluid ounces of water with the preload. After the blood glucose measurement and appetite rating at 12:00 pm, participants were given a test meal, from which they were instructed to eat *ad libitum*. The test meal included fruits, vegetables, hummus, deli meats, cheese, yogurt, and desserts. The participants were allowed 30 minutes to eat. At 12:30 PM, participants completed a final appetite rating (no blood glucose measurement). Participants were free to leave the laboratory immediately following the final appetite rating at 12:30 pm. The meal components were weighed when the participant left.

Overview of Work Completed and in Progress:

Over the first 6 months of grant funding, all necessary equipment was acquired to set up the clinical lab located in the Health Sciences Building in room 320R. This room was completely empty prior to commencing this study. The lab is now capable of running four human subjects at a time (Figure 1). Additionally, the IRB application for this study was approved, a website was created (labs.wsu.edu/foodlab). Each grain used in this trial was analyzed for gross energy, total dietary fiber, protein, amylose, and beta-glucan (Table 1). See consort diagram for screenings and other study procedures completed (Figure 2.)

To strengthen predictions of beta-glucan and protein using Dr. Murphy's NIR equipment, 224 barley samples were analyzed using the NIR with 132 also analyzed using enzymatic assays for beta-glucan determination. 132 of these samples have been run through the Leco protein analyzer located at the Western Wheat Quality lab.

Trial was concluded in March 2020 following the WSU requirement to suspend human subject research.

Manuscript draft is in progress.

Methods

Grain analysis

- Gross energy – Bomb calorimeter
- Protein – Leco protein analyzer (dumas method)
- TDF – Sigma enzymatic and gravimetric assay
- BG – Megazyme enzymatic assay
- Amylose – Megazyme enzymatic assay

Results

We are in the process of analyzing the results.

- Participant characteristics (Table 2)
- Energy intake and the weight of foods consumed at test lunch (Table 3)
- Temporal profiles of mean participant appetite ratings (Figure 3)

Publications, Handouts, Other Text & Web Products:

We currently have a website (labs.wsu.edu/foodlab) that describes the study and helped with recruitment.

Outreach & Education Activities:

Under supervision of Dr. Perrigue and Julianne Kellogg, one NEP Graduate student and four NEP Undergraduate students spent 3+ hours per week in the lab during Spring 2020, working on participant screening and assessment, meal preparation, data collection and entry, and other

activities designed to increase knowledge and proficiency in a Human Research Laboratory setting. All students reported this was a strong learning experience.

Julianne Kellogg presented a poster on the research at the 2019 American Seed Trade Association's seed expo in Chicago. She won first place in the poster presentation competition.

Additional presentations on the research topic and project:

- Kellogg, J. (2020). Biofortified barley. NEP 340 Food Science. WSU College of Medicine, Spokane, WA. October 23, 2020.
- Kellogg, J. (2020). Biofortification as a tool to tackle malnutrition: Experimentation in barley. Inland Northwest Research Symposium. WSU College of Medicine, Spokane, WA. March 27, 2020.

Impacts

Short-Term:

1. With the successful commencement of this trial, we have established the intended bridge between the Nutrition and Exercise Physiology Department and the Crop and Soil Sciences Department. Julianne Kellogg, a PhD student in Crop Science, is located at the WSU Spokane campus helping with this collaborative trial.

Intermediate-Term:

1. Increasing the accuracy of the NIR to estimate and rank beta-glucan and protein content will speed up the nutritional phenotyping process in the WSU barley program.

Long-Term:

1. Study findings will contribute to the growing body of evidence linking wholegrain barley β-glucan and positive health outcomes.

Additional funding applied for/secured:

Dept. of Nutrition and Exercise Physiology support for setting up the Food Lab

Dr. Perrigue's startup fund used to support setting up the Food Lab

Graduate students funded:

Julianne Kellogg, PhD candidate, Crop Science

Recommendations for future research:

No recommendations at this time.

Figure 1. WSU Elson S Floyd College of Medicine Food Lab layout

Figure 2. Consolidated Standards of Reporting Trials flow diagram

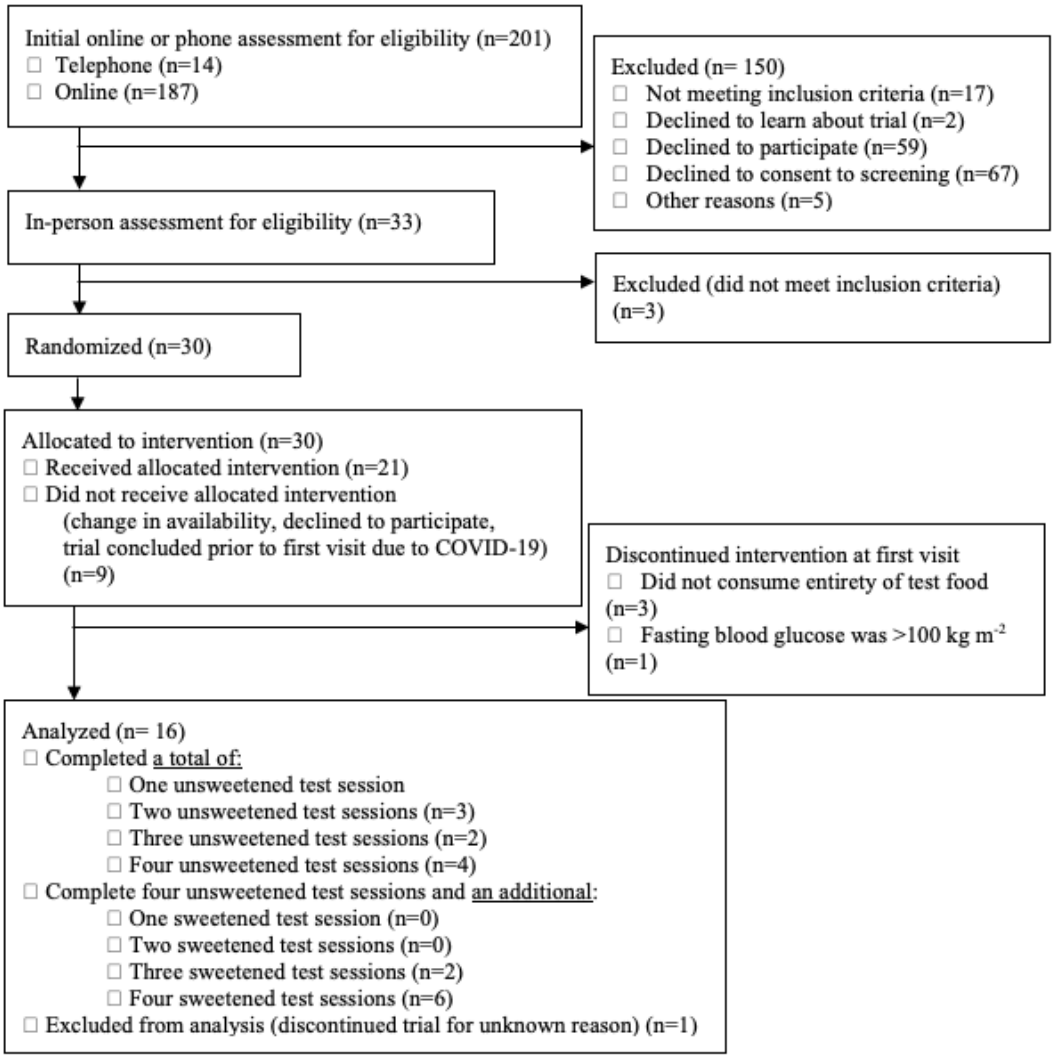

Figure 3. Temporal profiles of mean participant appetite ratings (composite appetite score) as a function of preload condition (WR, LB, MB, HB) and level of sweetness. Porridge was served immediately after baseline assessment (0 min) and test lunch was served at 240 min (dashed line). 95% compatibility intervals are reported for each timepoint.

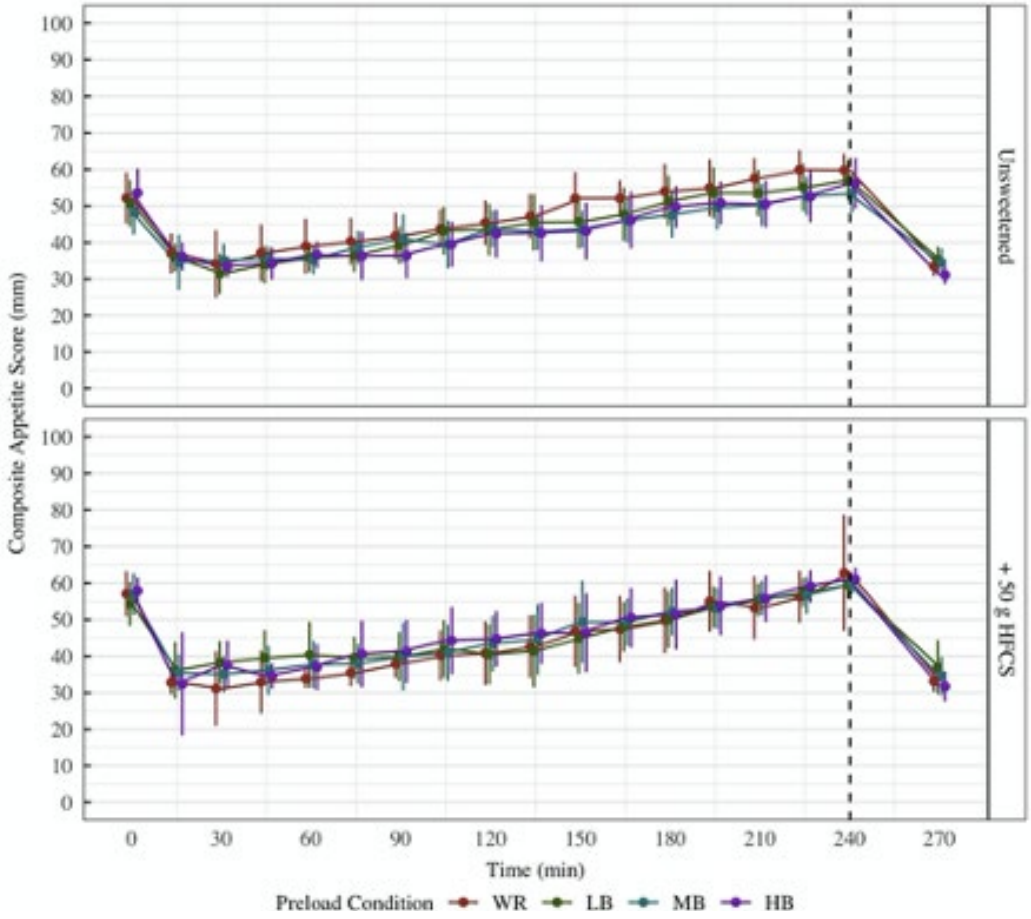

Table 1. Porridge content and nutrition facts

	High BG	**Med. BG**	**Low BG**	**Control**
Variety	Sustagrain Ardent Mills	Meg's Song WSU	Havener WSU	Glutinous white rice
Flour (g)	57	60	60	66
Water (g)	320	283	336	306
Protein (%)	12	7	6	5
TDF (%)	44	19	17	4
BG (%)	10	8	7	0

Table 2. Participant characteristics by gender (n = 16). Data displayed as means and standard deviation (SD).

	Males (n = 7)	**Females (n = 9)**	**Total (n = 16)**
Age (y)	32.3 (9.1)	28.8 (8.1)	30.3 (8.4)
Body Mass Index (kg/m2)	24.4 (1.9)	24.6 (4.6)	24.4 (3.6)
Weight (kg)	81.0 (5.5)	66.7 (15.2)	72.9 (13.8)
Blood glucose at screening (mg/dL)	89.6 (6.5)	89.6 (7.5)	89.6 (6.8)

Table 3. Energy intake (kcal) and the weight of foods and water (g) consumed at test lunch as a function of preload condition (WR, LB, MB, HB, SWR, SLB, SMB, SHB). Means and standard deviation (SD) displayed.

Preload condition	**Energy intake (kcal)**	**Food intake (g)**	**Food and water intake (g)**
White rice, control	830.6 (242.1)	589.8 (162.0)	1026.6 (185.1)
Low β-glucan barley	722.7 (259.2)	564.0 (168.8)	997.7 (197.1)
Medium β-glucan barley	649.8 (147.3)	489.9 (103.0)	906.3 (146.3)
High β-glucan barley	680.1 (176.0)	532.7 (139.4)	948.9 (181.9)
White rice + 50 g HFCS	797.3 (187.6)	572.9 (91.7)	1051.7 (158.9)
Low β-glucan barley + 50 g HFCS	827.6 (139.3)	616.8 (92.5)	1046.4 (166.2)
Medium β-glucan barley + 50 g HFCS	798.8 (202.8)	606.1 (124.9)	1032.65 (220.3)
High β-glucan barley + 50 g HFCS	815.0 (136.9)	613.6 (87.8)	1038.9 (150.2)