Differences in Gastrointestinal Symptoms, Stress, and Lifestyle Factors in Adults With and Without Irritable Bowel Syndrome After Consumption of Gluten and Inulin

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**Recommended Citation**

Stovern, Shelby; Zwack, Codi; Windsperger, Austin; Metelmann, Linnea; Johnson, Grace; Rooney, Elissa; and Milstroh, Jessica, "Differences in Gastrointestinal Symptoms, Stress, and Lifestyle Factors in Adults With and Without Irritable Bowel Syndrome After Consumption of Gluten and Inulin" (2022). *Celebrating Scholarship and Creativity Day*. 195.  
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Differences in Gastrointestinal Symptoms, Stress, and Lifestyle Factors In Adults With and Without Irritable Bowel Syndrome after Consumption of Gluten and Inulin

Shelby Stovern, Codi Zwack, Austin Windsperger, Linnea Metelmann, Grace Johnson, Elissa Rooney, Jessica Milstroh, and Dr. Alexa Evenson, RD, CFS

CSBSJU Scholarship and Creativity Day 2022
Overview of the Panel

Introduction & Literature review

Methods

Results/Discussion

Limitations/Future Research/Conclusion

Control vs Gluten Vs Inulin
Breath Hydrogen/GI Symptoms
Stress – Cortisol, PSS
Lifestyle Factors – PA, Sleep, Diet, Anxiety
Irritable Bowel Syndrome (IBS)

• Prevalence: 10-20% of the population worldwide and 10-15% of American adults
  • Twice as common in women compared to men
• Symptoms: cramping, abdominal pain, bloating, and abnormal bowel movement/patterns
• There are three subtypes:
  • Diarrhea-predominant (IBS-D)
  • Constipation-predominate (IBS-C)
  • Mixed (IBS-M) or Unclassified (IBS-U)
• Physiological response or intolerance to specific foods or food groups
• Created a 2nd study for us!

Lovell & Ford, 2012; Hadjivasilis, 2019
Dietary Intake and GI Symptoms

- Dairy – Those with IBS generally consume less dairy
  - Identified as Trigger Foods for Symptoms
  - Lactose Intolerance may be a reason for symptoms
- Fruits and Vegetables
  - Americans are not meeting the recommended amount
- Fruits/Veggies related to GI symptoms
  - IBS symptoms associated with higher intake of vegetables and fruit
- Fiber intake related to GI symptoms
  - Various GI symptoms from high-fiber fruits and vegetable foods
  - Insoluble Fiber vs. Soluble Fiber

Clevers, Egbert, et al., 2019; McCoy 2020
**FODMAPs and Gluten**

**FODMAPs (Inulin)**

- Fermentable oligosaccharides, disaccharides monosaccharides, and polyols
  - Inulin is a fructan (fructo-oligosaccharides)
  - Soluble non-viscous fiber
- Consuming a diet lower in FODMAPs may be beneficial in managing GI symptoms
  - Especially in those with IBS

**Gluten**

- Gluten is a protein
- Foods high in gluten: wheat, barley, rye
  - Gluten often found in high FODMAP foods
- Contradicting evidence on the effect on GI symptoms

Halmos & Gibson, 2019; Shepherd & Gibson, 2006; Hadjivasilis, 2019; Hajiani et al., 2019; Skodje et al., 2018
GI Symptoms + Breath Hydrogen

• H+ is produced when unabsorbed carbohydrates are fermented in the colon
• Analysis of hydrogen (H+) gas concentration in exhaled breath
• Increase of 20ppm = significant
• Individuals with IBS have increased breath H+ and GI symptoms following the consumption of FODMAPs

Erickson; Wang, et al., 2017; Korczak, et al. 2017; Ghoshal, 2020
Cortisol/Stress + GI Symptoms

- No studies directly comparing H+ and cortisol concentration
- An increase in cortisol levels = increase in the physiological stress response/GI symptoms

![Graph showing normal diurnal cortisol levels](image)

(Internal Salimetrics Data, n=26. Time of Cortisol peak will vary in individuals relative to their normal wake-up time.)

Wolfram et al., 2011; Balmus 2019; Salimetrics
Perceived Stress and GI Symptoms

• What is perceived stress?
• Previous research supported stress effecting GI symptoms
  • Diarrhea
  • Constipation
  • Lower abdominal pain
• Findings are self-reported
  • College age and faculty

Edman et al., 2017
**Satiety**

**INULIN**
- Consuming inulin has been shown to:
  - DECREASE hunger
  - INCREASE fullness
- Soluble fibers
  - Delay gastric emptying rates
  - Fermentable fiber

**GLUTEN**
- There is evidence on both sides of gluten and satiety as it has been shown to BOTH:
  - INCREASE and DECREASE fullness

Physical Activity & IBS Symptoms

• Studies do not indicate individuals with IBS refrain from exercise due to their symptoms

• High-intensity aggravates endothelial tight junctions causing systemic inflammation from leaking bacterial endotoxins

• Moderate-intensity significantly increases anti-inflammatory cytokines overall reducing abdominal pain

• Mod-Int PA – Butyrate (SCFA), promotes anti-inflammatory cytokines

• Yoga reduced GI symptoms equally to low-FODMAP diets and improved the quality of life

Codella et al., 2018; Costa et al., 2017; D'Silva et al., 2019 Maleki et al., 2018
Sleep In People With IBS

• Sleep disturbances in people with IBS are very commonly reported

• These sleep disturbances present as difficulty falling asleep, short duration, and frequent waking

• Poor sleep has been shown to emphasize the effect of certain gastrointestinal symptoms that cause disruptions in the sleep wake cycle

Tu Q. et.al., 2017, Patel. A. et. al., 2015
Anxiety and IBS

• Anxiety levels are significantly higher in individuals with IBS
• Generalized Anxiety Disorder: GAD-7
• STICSA
  • State and Trait Anxiety
  • Cognitive and Somatic Questions
• Trait anxiety found to be related to IBS in one study on GI disorders
  • More research needed using STICSA

Addolorato et al., 2008; Grös et al., 2007; Lee et al., 2017
Objectives/RQs

1. Was there a difference in Breath H+ and GI symptoms after consumption of gluten and inulin and did it differ between those with IBS and without?

2. Examine differences and relationships of stress (cortisol and perceived stress) in breath H+/GI symptoms
   - In non-IBS vs IBS
   - Limited studies on this

3. Examine how Lifestyle Variables may play a role in breath H+/GI symptoms based on Gluten or Inulin Consumption in those with IBS and without.
   - Diet, Physical Activity, Sleep, Anxiety
Methods
IBS Participants

Participants for the IBS group were selected based on GI symptoms that were related to common symptoms of IBS.

Participants were also asked if they were currently being treated for their symptoms, they were not selected for the study if they were being treated or taking medications for their symptoms or condition.
IBS - Rome IV Criteria

• An individual qualifies if meets two or more of the following criteria:
  • Symptoms suggestive of IBS for at least 6 months
  • Abdominal pain greater than or equal to 1 day/week within the last 3 months on average
  • Resolved pain after a bowel movement
  • Changes in stool frequency and/or appearance
    • Bristol Stool Chart used to determine IBS type (IBS-C, IBS-D, IBS-M, or IBS-U)
Research Design

• Randomized, Blinded, Crossover Design

• Inclusion/Exclusion
  • 18 years of age
  • BMI 18.5-29.9 kg/m²
  • No identified GI disorders or chronic diseases
  • Non-Smokers
  • Not Pregnant
  • Not taken antibiotics recently
  • Did not take prescription medications that alter GI function

Participants

• Mostly CSBSJU students/faculty
• n=24 non-IBS and n=14 IBS
• 12 females and 12 males – NON-IBS
• 11 females and 3 males – IBS
• Mean Age: 21.83 yrs vs 22.57 yrs
• Mean BMI: 23.11 kg/m² and 23.51 kg/m²
### Smoothie Recipe

**Ingredients:**
- 75 g frozen strawberries
- 38 g frozen raspberries
- 25 g frozen unripe banana
- 25 g soy protein powder
- 60 g Ocean Spray diet cranberry raspberry juice
- 75 g water
- 3 g liquid stevia
- 3 g liquid strawberry extract
- 5 g inulin or gluten powder (depending on treatment)

### Table 1. Nutrient Profile Between Smoothie Treatments

<table>
<thead>
<tr>
<th>Smoothie Type</th>
<th>Total Kcal</th>
<th>Total Fat (g)</th>
<th>Carbohydrates (g)</th>
<th>Fiber (g)</th>
<th>Sugar (g)</th>
<th>Protein (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>172.04</td>
<td>1.72</td>
<td>23.94</td>
<td>4.92</td>
<td>14.74</td>
<td>20.16</td>
</tr>
<tr>
<td>Gluten</td>
<td>195.54</td>
<td>1.82</td>
<td>24.63</td>
<td>4.92</td>
<td>14.74</td>
<td>24.92</td>
</tr>
<tr>
<td>Inulin</td>
<td>172.04</td>
<td>1.72</td>
<td>28.94</td>
<td>9.92</td>
<td>14.74</td>
<td>20.16</td>
</tr>
</tbody>
</table>
Breath Hydrogen/GI Symptoms

• Quintron Breath Tracker
• Used in clinical settings – Gold standard
• Uses solid-state sensors: H+, CH4, and CO2
• CO2 is measured to identify contamination of sample
  • CO2 should be consistent in breath composition from the lungs

• GI SYMPTOMS measured by questionnaire
  • Bloating, Gas, Nausea, Rumbling, Cramping, Constipation, Diarrhea

GI SYMPTOMS: Please select the severity of the intensity or frequency of the gastrointestinal symptoms you are experiencing at this time.

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Quite a lot</th>
<th>Severe</th>
<th>Very Severe</th>
<th>Unbearable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal bloating</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
</tr>
<tr>
<td>Nausea</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
<td>📸</td>
</tr>
</tbody>
</table>
Cortisol Collection

• Saliva was Collected at 4 times points using a collection aid to fill a cryovial.
  • Samples were kept in a portable cooler and then stored in -80°C after session.

• Salimetrics Expanded Range High Sensitivity Salivary Cortisol Enzyme Immunoassay (ELISA).

• Samples were analyzed ELISA Kit with samples ran in duplicate.

• A special THANK YOU to Dr. McIntee in the Chemistry Department for his help in completing cortisol assays!
Questionnaires

- Demographics
- GI Symptoms Survey
- PSS
- Dietary Intake
- VAS
- PSQI
- IPAQ-SF
- STICSA
**Perceived Stress Scale (PSS)**

- Perceived stress was assessed using the 10-Item Perceived Stress Scale

- Responses to questions consist of a scale of 0-4 (0=never and 4=very often)

- Scores ranging from
  - 0-13 indicated low perceived stress
  - 14-26 indicated moderate perceived stress
  - 27-40 indicated high perceived stress

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**Perceived Stress Scale**

A more precise measure of personal stress can be determined by using a variety of instruments that have been designed to help measure individual stress levels. The first of these is called the Perceived Stress Scale.

The Perceived Stress Scale (PSS) is a classic stress assessment instrument. The tool, while originally developed in 1983, remains a popular choice for helping us understand how different situations affect our feelings and our perceived stress. The questions in this scale ask about your feelings and thoughts during the last month. In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer fairly quickly. That is, don’t try to count up the number of times you felt a particular way; rather indicate the alternative that seems like a reasonable estimate.

<table>
<thead>
<tr>
<th>For each question choose from the following alternatives:</th>
<th>0 - never</th>
<th>1 - almost never</th>
<th>2 - sometimes</th>
<th>3 - fairly often</th>
<th>4 - very often</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. In the last month, how often have you been upset because of something that happened unexpectedly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. In the last month, how often have you felt that you were unable to control the important things in your life?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. In the last month, how often have you felt nervous and stressed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. In the last month, how often have you felt confident about your ability to handle your personal problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. In the last month, how often have you felt that things were going your way?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. In the last month, how often have you found that you could not cope with all the things that you had to do?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. In the last month, how often have you been able to control irritations in your life?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. In the last month, how often have you felt that you were on top of things?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. In the last month, how often have you been angered because of things that happened that were outside of your control?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NCI-DSQ Dietary Intake Questionnaires

- National Cancer Institute Dietary Screener Questionnaire (NCI – DSQ)
- This screener is a 26-item Dietary Screener Questionnaire (DSQ)
  - Asks about the frequency of consumption in the past month of selected foods and drinks
  - Fruits, Vegetables, F&V, Dairy, Added Sugar, Whole Grain, Fiber
VAS - Satiety

- Visual Analogue Scale
- Measures subjective appetite sensations
- Computerized scale - 100 mm lines
- 4 questions assessing:
  - Hunger
  - Satisfaction
  - Fullness
  - Volume
Pittsburgh Sleep Quality Index

The PSQI measures 7 different categories of sleep

- Sleep quality
- Sleep latency
- Sleep duration
- Habitual sleep efficiency
- Sleep disturbances
- Use of sleeping medications
- Daytime dysfunction

A score of 5 or more is indicative of poor sleep quality

The Pittsburgh Sleep Quality Index (PSQI) is an effective instrument used to measure the quality and patterns of sleep in adults. It differentiates "poor" from "good" sleep quality by measuring seven areas (components): subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction over the last month.

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

**During the past month,**

1. When have you usually gone to bed?
2. How long (in minutes) have you been to bed each night?
3. When have you usually woken up in the morning?
4. How many hours of actual sleep did you get at night?
5. How many times were you in bed?

A score of 5 or more is indicative of poor sleep quality

**Sleep Quality Assessment (PSQI)**

**What is PSQI, and what is it measuring?**

**INSTRUCTIONS:**
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

**During the past month,**

1. When have you usually gone to bed?
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4. How many hours of actual sleep did you get at night?
5. How many times were you in bed?

A score of 5 or more is indicative of poor sleep quality

**Scoring**

Component 1: #5 Score
Component 2: #2 Score (5-15) + #6 Score (6-10) + #7 Score (0-3)
Component 3: #4 Score (0-3) + #7 Score (4-10) + #8 Score (6-10)
Component 4: #4 Score (4-10) + #7 Score (6-10) + #8 Score (6-10)
Component 5: #6 Score (0-3) + #7 Score (4-10) + #8 Score (6-10)
Component 6: #6 Score (0-3) + #8 Score (4-10) + #9 Score (6-10)
Component 7: #6 Score (0-3) + #7 Score (4-10) + #8 Score (6-10)

**Global PSQI**

A total score of **5** or greater is indicative of poor sleep quality.

If you scored **5** or more it is suggested that you discuss your sleep habits with a healthcare provider.
IPAQ-SF Questionnaire

- International Physical Activity Questionnaire short form (IPAQ-SF)
- 7 items Questionnaire: vigorous, moderate, walking physical activity, and sedentary activity
  - Added yoga
  - 9 item total as it asks about frequency and duration

Meeus et al., 2011
STICSA Questionnaire

- State-Trait Inventory of Cognitive & Somatic Anxiety
  - 21 – item questionnaire for State Anxiety
    - 11 items = Somatic
    - 10 items = Cognitive
  - 21 – item questionnaire that assessed Trait anxiety
    - 11 items = Somatic
    - 10 items = Cognitive
  - Measured on a scale of 1 – 4 (1 = not at all and 4 = very much so)
  - The items are categorized into 6 sub-groups: State Somatic, State Cognitive, State Total, Trait Somatic, Trait Cognitive, and Trait Total.
  - The sum of each sub-groups was calculated based on the responses received.

<table>
<thead>
<tr>
<th>Item</th>
<th>STICSA State</th>
<th>STICSA Trait</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Heart beats fast.</td>
<td>.67</td>
<td>.64</td>
</tr>
<tr>
<td>2. Muscles are tense.</td>
<td>.57</td>
<td>.63</td>
</tr>
<tr>
<td>3. Feel agitated over problems.</td>
<td>.65</td>
<td>.70</td>
</tr>
<tr>
<td>4. Think others won’t approve.</td>
<td>.57</td>
<td>.70</td>
</tr>
<tr>
<td>5. Can’t make up mind.</td>
<td>.51</td>
<td>.57</td>
</tr>
<tr>
<td>6. Feel dizzy.</td>
<td>.62</td>
<td>.62</td>
</tr>
<tr>
<td>7. Muscles feel weak.</td>
<td>.62</td>
<td>.62</td>
</tr>
<tr>
<td>8. Feel trembly and shaky.</td>
<td>.71</td>
<td>.72</td>
</tr>
<tr>
<td>9. Picture future misfortunes.</td>
<td>.74</td>
<td>.72</td>
</tr>
<tr>
<td>10. Can’t get thoughts out of mind.</td>
<td>.76</td>
<td>.77</td>
</tr>
<tr>
<td>11. Trouble remembering things.</td>
<td>.50</td>
<td>.46</td>
</tr>
<tr>
<td>12. Face feels hot.</td>
<td>.73</td>
<td>.70</td>
</tr>
<tr>
<td>13. Think worst will happen.</td>
<td>.56</td>
<td>.57</td>
</tr>
<tr>
<td>14. Arms and legs feel stiff.</td>
<td>.58</td>
<td>.62</td>
</tr>
<tr>
<td>15. Throat feels dry.</td>
<td>.61</td>
<td>.66</td>
</tr>
<tr>
<td>16. Avoid uncomfortable thoughts.</td>
<td>.55</td>
<td>.50</td>
</tr>
<tr>
<td>17. Irrelevant thoughts intruding.</td>
<td>.76</td>
<td>.63</td>
</tr>
<tr>
<td>18. Breathing is fast and shallow.</td>
<td>.69</td>
<td>.60</td>
</tr>
<tr>
<td>19. Cannot control thoughts.</td>
<td>.75</td>
<td>.72</td>
</tr>
<tr>
<td>20. Butterflies in the stomach.</td>
<td>.65</td>
<td>.66</td>
</tr>
<tr>
<td>21. Palms feel clammy.</td>
<td>.62</td>
<td>.57</td>
</tr>
</tbody>
</table>

Note: STICSA = State-Trait Inventory for Cognitive and Somatic Anxiety. All factor loadings were significant at p < .05. Items are derived from State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA)—State Version, by Melissa J. Ree, Colin MacLeod, Davina French, and Vance Locke, 2000, Perth, Australia: The University of Western Australia. Copyright 2000 by Melissa J. Ree, Colin MacLeod, Davina French, and Vance Locke. Reprinted with permission.
METHODS

Baseline (Fasted)
- Breath Hydrogen
- Cortisol
- GI Symptoms
- PSS
- VAS
- IPAQ-SF
- State and Trait Anxiety

Drink Smoothie (w/in 10 minutes)
- Sensory Analysis
- VAS at 10 minutes

1 Hour
- Breath Hydrogen
- Cortisol
- GI Symptoms
- VAS

1.5 Hour
- GI Symptoms
- VAS

3 Hours
- Breath Hydrogen
- Cortisol
- GI Symptoms
- VAS

2 Hours
- Breath Hydrogen
- Cortisol
- GI Symptoms
- VAS

12 & 24 Hours
- GI Symptoms

Additional Questionnaires (1st Data Collection ONLY)
- Demographic
- NCI Dietary Screener
- PSQI

CZ
• Statistical Analysis

• SPSS IBS Version 28
• Descriptive statistics: Means $\pm$ SD
• AUC
• Multiple Repeated Measures ANOVA with LSD post-hoc
• ANOVA with simple effects tests
• Pearson $r$ and Spearman rho Correlation Coefficients
• Independent t-tests
• Significance was set to $p<0.05$
Results and Discussion
Results – Breath Hydrogen

- There were no differences in breath hydrogen between treatments or groups (p>0.05).
- Unexpected
  - 5g of gluten or inulin

Table 2. Differences in Breath Hydrogen AUC Between Treatments and Groups.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-IBS (n=24)</th>
<th>IBS (n=14)</th>
<th>F</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.96 ± 3.42</td>
<td>3.75 ± 4.48</td>
<td>0.00</td>
<td>0.971</td>
<td>0.000</td>
</tr>
<tr>
<td>Gluten</td>
<td>12.31 ± 6.04</td>
<td>-2.661 ± 7.91</td>
<td>2.26</td>
<td>0.141</td>
<td>0.059</td>
</tr>
<tr>
<td>Inulin</td>
<td>11.81 ± 5.19</td>
<td>-1.00 ± 6.79</td>
<td>2.25</td>
<td>0.143</td>
<td>0.059</td>
</tr>
</tbody>
</table>

Figure 1. Average breath hydrogen data over three hours with treatments in non-IBS participants.

Figure 2. Average breath hydrogen data over three hours with treatments in IBS participants.
Results – Total GI Symptoms

- GI symptoms differed between gluten and inulin treatments in non-IBS group, with gluten producing fewer GI symptoms.
- IBS group had more total GI symptoms than non-IBS group for control, gluten, and inulin treatments.
- Expected results between groups
  - Gluten improves symptoms – unclear connection

| Table 3. Differences in Total GI Symptoms AUC Between Treatments and Groups |
|-------------------------------|-------------------|-----------------|---|---|---|
| treatment | Non-IBS (n=24)      | IBS (n=14)       | F  | p     | η2  |
| Control   | 35.91 ± 37.38       | 109.13 ± 92.89   | 11.83 | 0.001 | 0.247 |
| Gluten    | 20.00 ± 30.31       | 74.57 ± 62.63    | 13.14 | 0.001 | 0.267 |
| Inulin    | 37.45 ± 47.62       | 93.79 ± 107.44   | 5.00  | 0.032 | 0.122 |

Erickson, Korczak, et al., 2017; Hadjivasilis, 2019; Hajiani et al., 2019
Results – Individual GI Symptoms

- No differences in GI symptoms between treatments in IBS – IBS participants just had more GI symptoms to start with and experienced throughout
- Comparable to previous research – IBS patients just have more GI symptoms

Table 4. Differences in Individual GI Symptoms AUC Between Treatments and Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment</th>
<th>Non-IBS (n=24)</th>
<th>IBS (n=14)</th>
<th>F</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloating</td>
<td>Control</td>
<td>8.19 ± 14.42</td>
<td>25.18 ± 19.59</td>
<td>9.41</td>
<td>0.004</td>
<td>0.207</td>
</tr>
<tr>
<td></td>
<td>Gluten</td>
<td>4.45 ± 8.90</td>
<td>22.84 ± 16.53</td>
<td>20.04</td>
<td>&lt;0.001</td>
<td>0.358</td>
</tr>
<tr>
<td></td>
<td>Inulin</td>
<td>9.27 ± 14.65</td>
<td>22.71 ± 20.65</td>
<td>5.49</td>
<td>0.025</td>
<td>0.132</td>
</tr>
<tr>
<td>Gas</td>
<td>Control</td>
<td>7.45 ± 12.28</td>
<td>21.23 ± 22.01</td>
<td>6.913</td>
<td>0.018</td>
<td>0.147</td>
</tr>
<tr>
<td></td>
<td>Gluten</td>
<td>3.75 ± 6.06</td>
<td>16.36 ± 16.29</td>
<td>11.78</td>
<td>0.002</td>
<td>0.247</td>
</tr>
<tr>
<td></td>
<td>Inulin</td>
<td>8.35 ± 13.92</td>
<td>16.96 ± 21.09</td>
<td>2.305</td>
<td>0.138</td>
<td>0.060</td>
</tr>
<tr>
<td>Constipation</td>
<td>Control</td>
<td>5.44 ± 12.89</td>
<td>13.71 ± 32.20</td>
<td>1.260</td>
<td>0.269</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>Gluten</td>
<td>2.14 ± 6.14</td>
<td>15.27 ± 29.11</td>
<td>4.620</td>
<td>0.038</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td>Inulin</td>
<td>4.44 ± 9.68</td>
<td>14.13 ± 33.26</td>
<td>1.806</td>
<td>0.187</td>
<td>0.048</td>
</tr>
<tr>
<td>Cramping</td>
<td>Control</td>
<td>1.41 ± 2.87</td>
<td>13.36 ± 22.83</td>
<td>6.529</td>
<td>0.015</td>
<td>0.154</td>
</tr>
<tr>
<td></td>
<td>Gluten</td>
<td>1.94 ± 6.40</td>
<td>7.39 ± 17.11</td>
<td>1.994</td>
<td>0.166</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td>Inulin</td>
<td>3.15 ± 9.31</td>
<td>14.20 ± 30.39</td>
<td>2.776</td>
<td>0.104</td>
<td>0.072</td>
</tr>
</tbody>
</table>
Results – Cortisol

- Within standardized ranges and similar to previous research
- No differences in cortisol between non-IBS and IBS groups

![Graph showing cortisol levels over three hours with treatments in non-IBS participants.]

![Graph showing breath hydrogen levels over three hours with treatments in IBS participants.]

Table 5. Differences in Cortisol AUC Between Treatments and Groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-IBS (n=24)</th>
<th>IBS (n=14)</th>
<th>F</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.06 ± 0.38</td>
<td>1.15 ± 0.35</td>
<td>0.58</td>
<td>0.453</td>
<td>0.016</td>
</tr>
<tr>
<td>Gluten</td>
<td>1.32 ± 0.47</td>
<td>1.31 ± 0.68</td>
<td>0.00</td>
<td>0.992</td>
<td>0.000</td>
</tr>
<tr>
<td>Inulin</td>
<td>1.36 ± 0.67</td>
<td>1.07 ± 0.33</td>
<td>2.07</td>
<td>0.159</td>
<td>0.056</td>
</tr>
</tbody>
</table>

Aardal & Holm, 1995; Stachowicz & Lebiedzińska, 2016; Salimetrics
Results – Perceived Stress

- Perceived stress did not differ between treatments or IBS groups ($p>0.05$)
  - Compared to other studies – difference

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-IBS (n=24)</th>
<th>IBS (n=14)</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18.46 ± 5.78</td>
<td>16.57 ± 6.05</td>
<td>0.91</td>
<td>0.35</td>
<td>0.03</td>
</tr>
<tr>
<td>Gluten</td>
<td>17.02 ± 6.18</td>
<td>16.14 ± 5.90</td>
<td>0.21</td>
<td>0.65</td>
<td>0.01</td>
</tr>
<tr>
<td>Inulin</td>
<td>15.96 ± 6.42</td>
<td>16.93 ± 4.53</td>
<td>0.25</td>
<td>0.62</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Fouquette, L. (2022)
Results – Satiety

- There was a significant difference in AUC for hunger between control and inulin treatments (MD=-6.18; p=0.024) for Non-IBS participants.
- There were also significant differences in AUC for fullness between control vs inulin (MD=5.96; p=0.026) and gluten vs inulin treatments (MD=6.74; p=0.016) in Non-IBS participants.
- There weren’t any differences between treatments in the IBS group or between the Non-IBS and IBS groups
  - Possibly due to increase in GI symptoms in IBS participants

<table>
<thead>
<tr>
<th></th>
<th>(n=24)</th>
<th>Control</th>
<th>Gluten</th>
<th>Inulin</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUNGER</td>
<td></td>
<td>119.90 ± 40.82</td>
<td>123.77 ± 49.14</td>
<td>141.52 ± 47.01</td>
<td>3.428</td>
<td>0.041*</td>
</tr>
<tr>
<td>SATISFACTION</td>
<td></td>
<td>140.18 ± 45.63</td>
<td>139.90 ± 60.94</td>
<td>128.70 ± 51.0</td>
<td>1.371</td>
<td>0.264</td>
</tr>
<tr>
<td>FULLNESS</td>
<td></td>
<td>139.30 ± 51.21</td>
<td>142.05 ± 58.95</td>
<td>118.45 ± 49.83</td>
<td>4.623</td>
<td>0.015*</td>
</tr>
<tr>
<td>VOLUME</td>
<td></td>
<td>147.30 ± 40.75</td>
<td>133.49 ± 52.38</td>
<td>155.27 ± 49.73</td>
<td>2.442</td>
<td>0.098</td>
</tr>
</tbody>
</table>
Results – Physical Activity IBS vs Non-IBS

• There was no difference between the 3 treatments in any of the groups (p > 0.05)
• Physical activity minutes and METs did not correlate breath hydrogen levels
• Physical activity levels were not comparable to other studies

| Table 8. Differences in Physical Activity Mets Between Treatments and Groups |
|-----------------------------------------------|----------------|----------------|------|------|
| Treatment                        | Non-IBS (n=24) | IBS (n=14)     | F    | P    |
| Vigorous Mets                      |                |                |      |      |
| Control                           | 54.76±41.61    | 46.04±30.29    | 0.470| 0.498|
| Gluten                            | 47.62±39.07    | 57.55±54.32    | 0.427| 0.517|
| Inulin                            | 48.10±37.71    | 59.10±53.22    | 0.555| 0.461|
| Moderate Mets                     |                |                |      |      |
| Control                           | 17.26±11.23    | 18.90±13.80    | 0.158| 0.693|
| Gluten                            | 23.17±35.96    | 16.33±12.09    | 0.472| 0.497|
| Inulin                            | 32.62±67.83    | 18.57±18.10    | 0.571| 0.455|
| Walking Mets                      |                |                |      |      |
| Control                           | 18.56±19.17    | 20.68±15.65    | 0.122| 0.719|
| Gluten                            | 36.67±50.76    | 21.89±17.53    | 1.100| 0.301|
| Inulin                            | 26.91±28.98    | 19.87±20.96    | 0.631| 0.432|
## Results - STICSA IBS vs Non-IBS

- No significant differences in trait anxiety between treatments and groups
- Mean state cognitive and state total anxiety significantly higher in IBS group with inulin treatment
- Mean state total score is <40 indicating a low probability of anxiety

### Table 9. Differences in State Anxiety Between Treatments and Groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-IBS (N=24)</th>
<th>IBS (N=14)</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State Somatic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>14.20 ± 3.61</td>
<td>15.14 ± 4.25</td>
<td>0.597</td>
<td>0.445</td>
</tr>
<tr>
<td>Gluten</td>
<td>14.29 ± 4.42</td>
<td>14.35 ± 3.12</td>
<td>0.002</td>
<td>0.962</td>
</tr>
<tr>
<td>Inulin</td>
<td>13.20 ± 2.62</td>
<td>13.92 ± 3.47</td>
<td>5.24</td>
<td>0.474</td>
</tr>
<tr>
<td><strong>State Cognitive</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>15.75 ± 5.60</td>
<td>18.85 ± 6.99</td>
<td>2.263</td>
<td>0.141</td>
</tr>
<tr>
<td>Gluten</td>
<td>14.83 ± 5.78</td>
<td>17.00 ± 5.75</td>
<td>1.246</td>
<td>0.272</td>
</tr>
<tr>
<td>Inulin</td>
<td>14.50 ± 4.38</td>
<td>18.07 ± 5.55</td>
<td>4.817</td>
<td>0.035</td>
</tr>
<tr>
<td><strong>State Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>29.95 ± 7.88</td>
<td>33.00 ± 9.59</td>
<td>1.12</td>
<td>0.297</td>
</tr>
<tr>
<td>Gluten</td>
<td>29.12 ± 8.77</td>
<td>31.28 ± 7.87</td>
<td>0.576</td>
<td>0.453</td>
</tr>
<tr>
<td>Inulin</td>
<td>27.70 ± 5.94</td>
<td>32.00 ± 6.48</td>
<td>4.314</td>
<td>0.045</td>
</tr>
</tbody>
</table>
Results - Sleep

• PSQI Score > 5 = Poor Sleep Quality
• There was no significant difference between the IBS and Non-IBS groups regarding sleep quality
  • No correlation between sleep and cortisol (AUC) in both groups
  • Relationship between perceived stress and sleep, but not cortisol in both groups
• Sleep is not significantly related to GI distress

Table 10. Differences in Sleep Scores Between Non-IBS and IBS Participants

<table>
<thead>
<tr>
<th></th>
<th>Non-IBS (n=24) Mean±SD</th>
<th>IBS (n=14) Mean±SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.75 ± 2.95</td>
<td>6.79± 3.24</td>
<td>1.007</td>
<td>0.321</td>
</tr>
</tbody>
</table>
Results - Dietary Intake

- There was no correlation of any dietary intake variable to breath hydrogen or GI
- There was no significant difference between IBS and non-IBS groups
- IBS subjects trending to eat less dairy

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-IBS (n=24)</th>
<th>IBS (n=14)</th>
<th>t, df=36</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit (cups)</td>
<td>1.22 ± 0.57</td>
<td>1.39 ± 0.61</td>
<td>0.833</td>
<td>0.410</td>
</tr>
<tr>
<td>Veggies (cups)</td>
<td>1.17 ± 0.66</td>
<td>1.81 ± 0.37</td>
<td>0.512</td>
<td>0.612</td>
</tr>
<tr>
<td>F&amp;V (cups)</td>
<td>2.87 ± 0.94</td>
<td>3.12 ± 0.95</td>
<td>0.786</td>
<td>0.437</td>
</tr>
<tr>
<td>Dairy (cups)</td>
<td>2.52 ± 1.40</td>
<td>1.81 ± 0.70</td>
<td>-1.763</td>
<td>0.086</td>
</tr>
<tr>
<td>AS (tsp)</td>
<td>16.29 ± 4.33</td>
<td>15.73 ± 3.09</td>
<td>-0.424</td>
<td>0.674</td>
</tr>
<tr>
<td>WG (oz)</td>
<td>0.98 ± 0.45</td>
<td>1.11 ± 0.42</td>
<td>0.873</td>
<td>0.388</td>
</tr>
<tr>
<td>Fiber (g/day)</td>
<td>18.48 ± 4.04</td>
<td>18.87 ± 3.61</td>
<td>0.303</td>
<td>0.764</td>
</tr>
</tbody>
</table>

Desmond, 2020
Limitations

Mostly college students

Our IBS participants were mostly female

Long duration of data collection (spanning D block, Summer, and Fall/Early Spring Semesters)

We didn’t ask about all medications that could have impacted gut motility

People may have had functional GI issues and self-selected into the study

We relied on many subjective measurements – Physical activity, sleep, diet, stress, anxiety, satiety.
Future Research

- Increase amounts of Gluten and Inulin to see if there are larger effects
- Try and collect data in a shorter period (over 3 months rather than a year)
- Could try Gluten and Inulin in different Food Matrices (solid)
- Control for food intake after consuming the smoothie – GI symptoms
- Standardize saliva collection to 30 minutes after waking for cortisol
- Try to physically measure some variables like PA and sleep
- Include more participants of different ages, races/ethnicities
Main Take Away Points/Summary

• In this sample of participants, the restriction of gluten and inulin in the diet (at 5 grams) is not warranted for those with and without IBS, as neither treatment produced a significant increase in breath hydrogen or GI symptoms.

• In those with IBS, there were increased GI symptoms to start with, indicating more GI distress but not related to the consumption of gluten or inulin at the 5-gram level.

• Lifestyle Variables
  • No correlations were found between diet, physical activity, sleep, anxiety, and breath hydrogen and GI symptoms for any treatment.

• More research is needed as the relationship between cortisol, breath hydrogen, and GI symptoms is still unclear.
REFERENCES


Thank you

• We'd like to thank our research (and life) advisor, Dr. Alexa Evenson for all her hard work throughout this project.

• A special THANK YOU to Dr. Ed McIntee in the Chemistry Department for his help in completing cortisol assays.

• CSBSJU Undergraduate Research and Nutrition Department for Funding our study!