Health Benefits of Barley
Effect of Barley Consumption on Glucose, Insulin, and Lipid Metabolism

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WHY BARLEY?

Barley is a grain product that is among the oldest foodstuffs in the world, is an excellent source of dietary fiber and in particular the soluble fiber, beta-glucan, and also is a good source of iron, selenium, and niacin.
The National Barley Foods Council, www.barleyfoods.org, which includes the Idaho Barley Commission, www.idahobarley.org, led the effort that requested funds from Congress for the conduct of research on barley in the areas of disease resistance, genetic development, promoting improved yields and effects on human health.

Congress mandated that research be done within USDA’s Agricultural Research Service on specific barley related projects, including the Health Benefits of Barley.

This barley research is an example of the mission related research conducted in nutrition at the USDA, Agricultural Research Service.
BARLEY

- Classified by number of kernel rows on the head, two-row, four-row and six-row

- Hulled and Hulless
  - Dehulled (lightly pearled) and hulless forms of barley are classified as whole grains
Wholegrain Barley

**CARBOHYDRATES**
- STARCH – 55%
- FIBER – 15%
  - Beta-glucan

**LIPIDS** – 3%
- Tocotrienols

**PROTEIN** – 12%

**MICRONUTRIENTS**
- Vitamins
- Minerals
- Phenolic Acids
- Flavonoids
- Anthocyanins
Barley grain structure

Covered: cemented hull
Barley grain structure

Hulless: loose hull
Historical Use of Barley

- **8000 BC**
  Domestication in the Fertile Crescent

- **Ethiopia**
  King of grains

- **Egypt**
  Food, Beverages, Religious rites, Funerals, Medicine, Trade

Tablet describing barley rations in Iraq in 2351-2342 BC as payment for working in a temple. Adults received 40 pints/month, children 20 pints/month.
Biblical References to Barley

From a Nuremburg Bible - David fighting in barley fields

Take for yourself wheat, barley, beans, lentils, millet, and spelt; put them into one vessel, and make bread of them for yourself.

Ezekiel 4:9
There is a boy here who has five barley loaves and two fish. But what are they among so many people? John 6:9
Historical Use of Barley

- Eastern Europe: Best crop for the high altitudes
- British Isles: 3000 BC, Barley preceded oats into Scotland, Oats became the cash crop while working class ate barley

1920’s England
Historical Use of Barley

Scandinavia

- Norway: 2000-1700 B.C.
- Denmark: First “clinical research trial”

Used in flatbread, breads, porridge, abraded kernels and grits
Historical Use of Barley

Asia

- India: Treatment of type 2 diabetes, barley tea and barley water
- Korea: Rice extender, beverages and condiments
- Tibet: “tsampas” a mixture of barley flour, tea and butter
Barley can withstand very cold growing conditions.

Major production states are: North Dakota, Idaho, Montana, Washington, Colorado, Wyoming, Virginia, Minnesota, Maryland, South Dakota, Oregon and Utah.
BARLEY in the USA

- 1602-1629, Used mostly for making malt and beer
- Only 2 percent of the barley grown in the US is consumed as food products, with 44% for malt, and 51% for animal feed
- Food products include beverages, pearled barley in soups, pilaf mixes, barley flakes, flour and grits in cereals and baked goods and whole grain barley products in granolas
Definition of Terms

Whole Grain

Dietary Fiber
FDA Definition of Whole Grain

FDA takes a “Whole Grain” to include cereal grains that consist of the intact, ground, cracked or flaked fruit of the grains whose principal components -- the starchy endosperm, germ and bran -- are present in the same relative proportions as they exist in the intact grain. Such grains may include barley, buckwheat, bulgur, corn, millet, rice, rye, oats, sorghum, wheat and wild rice.
What is wholegrain barley?

- Hulless
- Hulled (or dehulled)
- Pot or
- Regular Pearl
- Medium Pearl - brown
Institute of Medicine’s Food and Nutrition Board Proposed Definition of Dietary Fiber

Dietary Fiber consists of nondigestible carbohydrates and lignin that are intrinsic and intact in plants

- **Insoluble Fiber** – in not soluble in the matrix of the intestinal “soup”

- **Soluble Fiber** – is soluble in the intestinal “soup” and therefore has differing effects from insoluble fiber
Institute of Medicine’s
Food and Nutrition Board
Proposed Definition of Dietary Fiber

- Added Fiber consists of isolated, nondigestible carbohydrates that have beneficial physiological effects on humans and are added to foods
- Total Dietary Fiber is the sum of dietary fiber and added fiber
**USDA/DHHS Dietary Guidelines**

**Recommendations for Dietary Fiber Intake**

- 14 grams/1000 kilocalories consumed
- Recommended Fiber Intake is therefore 25-38 g of fiber per day
- Average intake is 12-15 g
Grains - Grams of Fiber per 40 grams

- Oat Bran: 6.4
- Hulless Barley: 5.6
- Pearled Barley: 5
- Oatmeal WW: 4
- WW Bread: 2.8
- Brown Rice: 1.4
- White Rice: 0.5

- Total Fiber
- Soluble Fiber
Proposed health benefits of eating foods rich in soluble fibers

- Regulation of plasma lipids
- Regulation of glucose and insulin metabolism
- Major effect of fiber on lowering cholesterol and regulating insulin/glucose has been attributed to the soluble fiber beta-glucan
Effects of fiber consumption on the intestine

- Alters the thickness of the colonic mucus layer
- Changes the amount of Short Chain Fatty Acid Production in the Colon
- Alters colonic pH due to fermentation of the soluble fiber
- Alters the diameter and length of the intestine
- Alters intestinal intra-luminal viscosity
Whole wheat kernel

- **Bran**
  - Outer protective shell, Fiber, B vitamins and trace minerals

- **Endosperm**
  - Carbohydrates and Protein

- **Germ**
  - Antioxidants, vitamin E, B vitamins, phytonutrients, lipids
Beta-glucan Content of Cereal Grains

Barley (3-16%)

Oats (2-6%)

Wheat (0.5-1.5%)
Barley advantage

- In other grains, most of the beta-glucan is removed when the bran layer of the grain is removed.

- The soluble fiber, beta-glucan, is found throughout the entire barley kernel and therefore even refined products such as barley flour contain beta-glucan.
Fluorescence micrographs of waxy, hulless barley

A. Bz 489-30 & B. Sustagrain®

Sprouting Barley or Malting
Attributes of soluble fiber and disease risk

Short-term feeding studies

- Regulation of glucose and insulin metabolism
  - Plasma glucose and insulin response to a glucose drink or a carbohydrate “meal”
  - Fasting and follow-up blood samples

Long-term feeding studies

- Regulation of plasma lipids
  - Total, LDL and HDL cholesterol
  - Fasting blood samples
Effects of Consuming Barley on Blood Glucose and Insulin
Short term studies

- Sample size needed ~ 20
- Control food intake for 2 days
- Collect Fasting Blood Samples
- Provide volunteer with a glucose drink or barley or control “meal”
- Collect samples after drink or meal for 3 hours
Tolerance Test

- After an overnight fast, administer 75 g of glucose or a “breakfast” of a test product such as wheat, oats, or barley as cereal or bread product containing a specific amount of carbohydrate.
- Collect blood samples at fasting and selected time points for 3 hours.
- Analyze for glucose and insulin.
Glucose and Insulin Responses

- Simple Plots of plasma levels at specific time points
- Area under the curve (AUC) is determined mathematically as a sum of area of the rectangles that can be fit under the curve.
Barley dose response

Glucose

- Barley
- Spaghetti
- Bread
- Potato

Insulin

- Barley
- Spaghetti
- Bread
- Potato

Wolever & Bolognesi, 1996
Glucose AUC

Hallfrisch et al, Cereal Chem 80:80, 2003
Insulin Response After Barley and Oat

Hallfrisch et al, Cereal Chem 80:80,2003
Glucose and Insulin Responses to Fine and Coarse Breads

Glucose AUC after Oats or Barley

Glucose responses to an acute carbohydrate challenge

Insulin responses to an acute carbohydrate challenge

Summary

- Soluble fiber from barley and oats lower the acute glucose and insulin response to a meal.
- Barley improves the response greater than oats due to the higher beta-glucan content of the barley fed in the study.
- Barley beta-glucan content varies from 3-16%, while oat beta-glucan varies from 2-6%.
Factors Affecting Glucose & Insulin Response to a “Meal”

Age and ethnicity
Basal metabolic rate
Obesity - % Body Fat
Body fat distribution
Glucose disposal rate
Fiber content of meal

Intestinal absorption rate
Meal frequency
Gastric emptying rate
Fermentation in colon
Protein and fat content
Type and amount of carbohydrate
Barley and oats and their extracts with high levels of soluble fiber are effective in improving glycemic response and insulin sensitivity.

The type and characteristics of the person consuming the grain are important in the level of reduction that can be achieved.
Effects of Consuming Barley on Blood Lipids
USDA Controlled feeding studies

- 2 weeks - AHA Step 1 Diet Control – no added beta-glucan
- 5 weeks - Moderate – 3 g beta-glucan from barley per 2800 kcal/d
- 5 weeks- High – 6 g beta-glucan from barley per 2800 kcal/d
- \((\text{pancakes, muffins, granola, cakes, cookies})\)

30% FAT, 15% PRO, 55% CHO, < 300 mg cholesterol, 1g dietary fiber/100 kcal

Plasma total cholesterol

HDL Cholesterol

Plasma triglycerides

**Human study conclusions**

- Consumption of soluble fiber from barley significantly improved several cardiovascular risk factors.
- Soluble fiber from barley appears to be as effective in lowering plasma cholesterol as that from oats.
- Barley studies in DHPL have been used to support health claim petitions submitted to FDA.
Barley and Satiety
Dietary Fiber and Weight Control

- Increased stomach distention and intra-lumenal viscosity
- Decreased energy density and rate of gastric emptying & nutrient absorption
- Regulation of Gut Hormones

↑ Satiation - (the process leading to the cessation of eating including the effects of a meal or food after eating has terminated)

Reduced Energy Intake

 Increased Fat Oxidation & Decreased Fat Storage

Anti-obesity Effect

- Increased fermentation to short chain fatty acids by bacteria in colon
- Decreased plasma FFA

Adapted from Periera and Ludwig 2001 Ped Clin N Am 48:969-980
Satiety Study

Glucose, Whole Wheat and/or Barley Hot Cereal
Controlled feeding 1 day prior

Lunch

-15 0 15 30 60 120 Minutes

- Blood glucose – palm prick
- VAS questionnaires
Metabolic measurements

- Plasma Glucose
- Body Composition
  - Percent fat
  - Fat distribution (WHR)
- Measures of Satiety
  - Visual Analogue Scales rating hunger, fullness, nausea
How hungry are you?

VISUAL ANALOGUE SCALE (VAS)

0 mm

100 mm

Not At All Hungry

Slightly Hungry

Moderately Hungry

Very Hungry

Extremely Hungry

Greatest Imaginable Hunger
At 3 hours after breakfast each subject was offered a 2 quart casserole dish containing 2000kcal of macaroni and cheese and 1 liter of water and asked to eat as much as they cared to eat until they were comfortably full.
## Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 9)</th>
<th>Women (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>57.2 ± 3.3</td>
<td>50.9 ± 2.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.4 ± 1.9</td>
<td>163.5 ± 1.9*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>92.8 ± 2.8</td>
<td>85.3 ± 4.4</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.2 ± 0.7</td>
<td>31.8 ± 1.2*</td>
</tr>
<tr>
<td>Percentage body fat (%)</td>
<td>29.1 ± 1.4</td>
<td>44 ± 1.2*</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>104 ± 2.4</td>
<td>102 ± 3.3</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.96 ± 0.01</td>
<td>0.88 ± 0.01*</td>
</tr>
<tr>
<td>Fasting blood glucose (mg/dL)</td>
<td>101.6 ± 3.3</td>
<td>101.9 ± 3.1</td>
</tr>
</tbody>
</table>

Kim, Behall & Conway Cereal Foods World 5:29, 2006
## Food Content And Composition Of Test Meals

4 Test Meals (300 Kcal) (Latin-Square Design)

<table>
<thead>
<tr>
<th></th>
<th>Glucose</th>
<th>0 g of beta-glucan (0 BG)</th>
<th>1 g of beta-glucan (1 BG)</th>
<th>2 g of beta-glucan (2 BG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (g)</td>
<td>–</td>
<td>50</td>
<td>25</td>
<td>–</td>
</tr>
<tr>
<td>Barley (g)</td>
<td>–</td>
<td>–</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Yogurt (g)</td>
<td>–</td>
<td>106</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>PRO (g)</td>
<td>–</td>
<td>9.2</td>
<td>9.1</td>
<td>9.1</td>
</tr>
<tr>
<td>CHO (g)</td>
<td>75</td>
<td>58.3</td>
<td>59.1</td>
<td>59.8</td>
</tr>
<tr>
<td>FAT (g)</td>
<td>–</td>
<td>3.3</td>
<td>3.4</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Kim, Behall & Conway Cereal Foods World 5:29, 2006
AUC % initial glucose

Kim, Behall & Conway Cereal Foods World 5:29, 2006
Kim, Behall & Conway Cereal Foods World 5:29, 2006
Energy Intake at Lunch

Kim, Behall & Conway Cereal Foods World 5:29, 2006
Glucose response was lower when the women consumed 1 and 2 g of beta-glucan from barley cereal for breakfast.

Women but not men seemed to have a greater sense of satisfaction after consuming a breakfast high in beta-glucan.

No difference in energy consumed at lunch was seen in either men or women.
On December 23, 2005, the US Food and Drug Administration (FDA) authorized use of a health claim for the role of beta-glucan soluble fiber from barley in reducing the risk of coronary heart disease.

The FDA amended CFR 101.81, the regulation authorizing a health claim on the relationship between oat beta-glucan soluble fiber and reduced risk of coronary heart disease to include barley as an additional eligible source of beta-glucan soluble fiber.
BARLEY HEALTH CLAIM

A food made from eligible barley sources must contain at least 0.75 grams of beta-glucan soluble fiber per serving. Health claim CFR 101.81 is based on eating a total of 3 grams of beta-glucan soluble fiber daily.
## BARLEY HEALTH CLAIM

<table>
<thead>
<tr>
<th>Type of Barley Product</th>
<th>% Fiber Dry weight basis</th>
<th>% Beta Glucan Dry weight basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehulled and hulless barley</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Barley flakes</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Barley grits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearl barley</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Barley flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley meal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley Bran</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>Sieved Barley Meal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BARLEY HEALTH CLAIM

What barley products qualify as eligible beta-glucan soluble fiber sources?

• whole grain barley
• barley bran
• barley flakes
• barley flour
• barley grits
• barley meal
• pearl barley
• sieved barley meal
WHOLE GRAINS
DIETARY FIBER AND COPASSENGERS*

* Adapted from Vaasan and Vaasan, Finland
Biologically Active Compounds Found in Barley

- Prebiotic soluble fiber
- Flavinoids, Phenolic Acids, Anthocyanins
- Vitamins B and E
- Minerals Fe, Se
- Fats, Sphingolipids
Traditional benefits of barley consumption

- Prebiotic Activities (a prebiotic substance promotes the growth of certain bacteria thought to be beneficial in the intestines)
- Reduce High Cholesterol and prevent Cardiovascular disease
- Blood Glucose and Insulin Homeostasis is maintained better with barley than with oats, wheat or glucose

www.intelihealth.com
Traditional benefits of barley consumption

- Ulcerative Colitis – preliminary studies suggest that consumption of germinated barley foodstuffs may improve symptoms of ulcerative colitis

- Relieves Constipation – due to the presence of fiber

www.intelihealth.com
Barley Safety

- Well tolerated but allergic reactions have been reported to barley flour and to beer
- Gluten allergy – barley should be avoided by people with celiac disease and gluten intolerance
- Type II Diabetics who take drugs to lower blood sugar may need to exercise some caution until the proper dosage is established
- Barley based baby formulas (macrobiotic type) may not be nutritionally adequate for infants

www.intelihealth.com
Future Uses of Barley

- **Proprietary barley products**
  - ConAgra – Sustagrain™ is in the commercial market place as a barley that contains about 16% beta-glucan
  - Cargill - Barliv™ a beta-glucan isolate from barley will be available soon as an ingredient for fortified beverages

- **Novel Food Products**
  - From the laboratory of Nancy Ames of Canada
    - Tortillas
    - Nut substitutes

- **Addition of barley to food products**
  - Granolas and high fiber cereals
  - Breads
  - Confections
Utilization of the Attributes of Barley in Developing High Fiber Foods

Nancy Ames, Ph.D.
Cereal Research Centre, Winnipeg, Canada

Agriculture and Agri-Food Canada
Barley Tortillas and Chips

Nancy Ames, Ph.D.
Cereal Research Centre
Winnipeg, Canada

Agriculture and Agri-Food Canada
Barley Micronization

- Barley genotypes respond differently to infra-red heat treatment, leading to the creation of novel whole grain, high fiber food products.

Nancy Ames, Ph.D.
Cereal Research Centre
Winnipeg, Canada

Agriculture and Agri-Food Canada
“Minute” Barley

- Develop whole grain barley food products with quick cooking properties and desirable texture

Nancy Ames, Ph.D.
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Winnipeg, Canada

Agriculture and Agri-Food Canada
Nut Replacers

Utilize unique properties of specific barley cultivars to create whole grain nut replacers

Nancy Ames, Ph.D.
Cereal Research Centre
Winnipeg, Canada

Agriculture and Agri-Food Canada
Barley Foods – The Future
Thank you for your kind hospitality and attention