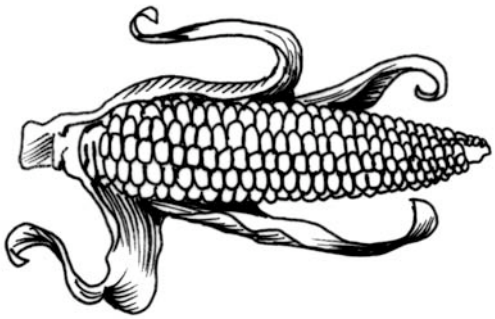
Health Benefits and Studies



The New Fiber Story:
Natural Resistant Starch
September 29, 2007, Philadelphia

Oldways
Hi-maize® Resistant Starch

Health Benefits & Studies

Natural resistant starch has many health benefits that result from its digestion and fermentation. The fermentation of natural resistant starch makes it different from many other types of dietary fiber and is believed to be responsible for metabolic health benefits. Here is a summary:

1. Weight Management

Natural resistant starch has been shown to assist in weight management via several mechanisms.

(a) Resistant starch lowers the calorie density of foods, delivering between 2 and 3 kilocalories/gram vs. 4 kcals/gram for flour.

(b) Eating just one meal containing Hi-maize resistant starch has been shown to switch your body to burning fat as its energy source instead of dietary carbohydrates.

(c) Hi-maize has been shown to increase the production of the satiety hormones GLP-1 and PYY in animal models.

(d) Natural resistant starch may assist in managing body composition. One clinical trial has demonstrated that consumption of Hi-maize resistant starch reduced Body Mass Index in Type 2 diabetics. Additional studies are needed to confirm this finding.

2. Blood Sugar Management

Resistant starch helps maintain healthy blood sugar levels in three ways: (1) it reduces the glycemic and insulin response of foods when it is used to replace flour, (2) it increases insulin sensitivity in healthy people as well as diabetics, and (3) it reduces the glycemic response of the subsequent meal.

3. Energy Management

Eating foods with resistant starch helps balance your energy in the hours following a meal because its energy is partially released in the small intestine as glucose and partially released in the large intestine as short-chain fatty acids (*i.e.,* acetate). In addition, it has a lower glycemic and insulin response than the flour it replaces, which helps to avoid the high peaks and low troughs of blood sugar between meals.

4. Digestive Health

Natural resistant starch helps to maintain a healthy intestinal system. As a prebiotic fiber, it encourages the growth of health-promoting bacteria, and reduces the number of harmful bacteria. Its fermentation increases the production of butyrate, a short-chain fatty acid with many anti-cancer and anti-inflammatory properties, and decreases potentially harmful compounds such as ammonia, phenols and secondary bile acids. It mildly promotes regularity in healthy individuals, and has been shown to be an effective treatment for diarrhea in adolescents and adults. Also, foods naturally rich in resistant starch have been found to be of benefit to individuals with ulcerative colitis.

5. Well Tolerated

Numerous studies have demonstrated that dietary consumption of natural resistant starches are well tolerated. Individuals can consume as much as the recommended daily dose of dietary fiber from natural resistant starches with minimal or no digestive side effects.

The health benefits above have been documented in a growing body of research that includes more than 160 peer-reviewed scientific studies.

Early indications show natural resistant starch may offer even more health benefits. While a solid body of evidence is building, the following areas of study demonstrate promise:

- Animal studies suggest that RS2 resistant starches **increase bioavailability of minerals** including calcium, but additional studies are needed to confirm this effect in humans.
- Animal studies also suggest that dietary consumption of high amylose corn RS2 **increases immune function**, but confirming human studies are needed.
- It may also play a **beneficial role in colonic diseases** such as ulcerative colitis and Crohn's disease. Additional research is needed to confirm this potential.
- Dietary consumption of high amylose corn RS may have a beneficial role in **reducing the risk of cardiovascular disease**, primarily through its ability to increase insulin sensitivity. Further research is needed to identify specific mechanisms and extent of the potential benefit.

In this section of the conference book, we will expand four of the major benefits above, then provide reference information for much of the scientific information presented at **The New Fiber Story: Natural Resistant Starch** Conference in Philadelphia, September 29, 2007 as well as other associated research.

Resistant Starch & Weight Management

"We already have shown that rats fed resistant starch have increased gut fermentation, increased intestinal expression of important peptides and decreased abdominal fat. We believe the fermentation of resistant starch may be an effective, natural approach to the treatment of obesity."

Dr. Mike Keenan
LSU AgCenter's School of Human Ecology

The Stats.[1]

- 136.5 million Americans (65.1%) are overweight or obese.
- 3.8 million American children (15.8%) between the ages of 6-12 are overweight or obese.
- 5.3 million American children (16.1%) between the ages of 12-19 are obese or overweight.

The Role of Resistant Starch

With obesity on the rise, focus on weight management continues to be a priority. In addition to adult complications, earlier onset of obesity-related diseases such as type 2 diabetes, are being reported in children and adolescents with obesity.

Studies show natural resistant starch is a valuable carbohydrate in foods designed for weight management.

The Positive Effects

Consumption of foods containing natural resistant starch positively affects weight management by:

- **Calorie reduction**: Hi-maize® resistant starch helps to reduce the caloric density of foods.
- **Lipid oxidation**: Hi-maize resistant starch helps your body burn more fat.[2]
- **Satiety**: Hi-maize resistant starch increases production of the satiety hormones GLP-1 and PYY.[3]
- **Body composition**: Hi-maize resistant starch reduces the deposition of fat in animal models.[4] In addition, one clinical trial has demonstrated that consumption of Hi-maize resistant starch reduced Body Mass Index in Type 2 diabetics. Further research is needed to confirm this benefit.

As a bonus for manufacturers, resistant starch also **lowers legal calorie-reporting requirements**. Per US labeling regulations, the insoluble fiber component of a natural resistant starch such as Hi-maize contributes 0 calories. This is why Hi-maize 260 delivers 1.4 Kcal/gram for US labeling. Actually, clinical studies have shown that high amylose corn resistant starch (RS2) delivers between 2-3 Kcal/gram, depending upon individual metabolism. Fully digested carbohydrates deliver 4 Kcal/gram.

Note: For consistency, scientists often use Hi-maize, an all-natural form of resistant starch made from corn, in studies.

1 *NHANES (1999-2002) as quoted in Heart Disease and Stroke Statistics – 2006 Update, American Heart Association*
2. Higgins, 2004 (Nutrition & Metabolism); Pawlak, 2004 (Lancet), Higgins, 2006 (Nutrition Journal)
3. Keenan, 2006 (*NAASO*), Keenan, 2006 (*Obesity*), Zhou, 2006 (*Obesity*)
4. Pawlak, 2004 (*Lancet),* Pawlak, 2001 (*Journal of Nutrition*), Keenan, 2006 (*Obesity*), Morita, 2005 (*Journal of Food Science*).

Resistant Starch & Digestive Health

"Our scientific interest in resistant starch is that resistant starch is turning out to be as important, and possibly more important, than [traditional] fiber for the health of the human bowel."

Dr David Topping, Chief Research Scientist,
CSIRO Health Sciences and Nutrition

The Stats

- 21.7 million Americans suffer from chronic intestinal disorders including IBS, Crohn's disease, ulcerative colitis, diverticular disease and chronic diarrhea.[1]
- Colorectal cancer is the third most common cancer in Americans, with 150,000 cases expected to occur in 2007.[2]
- 2.2 million Americans have Celiac disease and cannot eat foods with gluten from wheat, rye, barley, & triticale.[3]

The Role of Resistant Starch

Eating natural resistant starch, a form of fiber that minimally affects food flavor and texture, is important for colon health. Simple dietary and lifestyle changes can significantly increase the functioning and health of colonic tissue. Recent scientific studies suggest that resistant starch may also reduce the risk for colon cancer. Finally, it may also have a beneficial impact on those who are gluten intolerant or have inflammatory bowel disease.

The Positive Effects

Consumption of foods containing natural resistant starch positively affects digestive health by the factors below and on the following page:

- Selectively **increasing beneficial bacteria**, while suppressing harmful bacteria – what's called a 'prebiotic' fiber[4]
- **Increasing short-chain fatty acid production** (particularly butyrate, an important biomarker for colon health)
- **Reducing intestinal pH** and the production of potentially harmful ammonia and phenols
- **Increasing blood flow to and thickness of** the large intestine
- **Promoting regularity** with a mild laxative effect
- **Healing intestinal ulcerations** in an animal model for colitis[5]
- **Reducing diarrhea** when added to oral re-hydration solutions[6]

Continued…

[1] "The Burden of Gastrointestinal Diseases" 2001, American Gastroenterological Association
[2] American Cancer Society
[3] Fasano A.,. *et. al., Archives of Internal Medicine 163(3):286-292 (2003)*.
[4] Brown I, 1997 (The Journal of Nutrition.
[5] Moreau, 2004 (The Journal of Nutrition)
[6] Rangupathy, 2006 (Journal of Pediatric Gastroenterology & Nutrition), Ramakrishna, 2000 (New England Journal of Medicine), Subramanya , 2006 (Journal of Pediatric Gastroenterology & Nutrition)

More Positive Effects

Consumption of foods containing natural resistant starch also positively affects digestive health by:

- **Preventing DNA damage induced by carcinogenic agents**[7]
- **Preventing thinning of the protective mucous layer** in the presence of harmful agents such as high protein diets and other toxins.[8] Reduced thickness of the mucous layer is a feature of ulcerative colitis.
- **Aiding in the removal (apoptosis) of DNA-damaged cells** which may assist in reducing the risk of colon cancer[9]

Foods naturally rich in resistant starch have been shown to be beneficial in individuals with ulcerative colitis.[10]

[7] Toden, 2007 (Cancer Biology & Therapy)
[8] Morita, 2004 (Bioscience, Biotechnology & Biochemistry), Morita, 2004 (Journal of Gastroenterology & Hepatology), Toden, 2007 (*Cancer Biology & Therapy)*
[9] Toden, 2006 (Cancer Biology & Therapy), Le Leu, 2005 (Journal of Nutrition), Le Leu, 2007 (Carcinogenesis), Toden, 2007 (British Journal of Nutrition).
[10] Magee, 2005 (Nutrition Journal).

Resistant Starch & Energy Management

"It's exciting to see such a small dietary manipulation, just two meals a day containing resistant starch, can have such a big impact on the body's metabolism, especially for adults and children looking for a realistic, long-term healthy lifestyle plan."

Dr. Janine Higgins, Instructor,
Center for Human Nutrition,
University of Colorado Health Sciences Center

The Stats

- 45% of primary grocery shoppers report they are personally affected by tiredness & lack of energy[1]
- The 2005 Dietary Guidelines recommend three servings per day of whole grains, but Americans, on average, eat less than one.[2]
- The Guidelines also recommend we eat 8-10 servings of fruits and vegetables per day, but 77% of Americans eat 4 servings or fewer daily.
- The Institute of Medicine has set 130 grams as the daily minimum for carbohydrate consumption, based on the glucose needs of the brain.

The Role of Resistant Starch

One growing concern of consumers is energy management. During the day, people experience swings in blood sugar levels and energy depending on what they eat. For example, immediately following a meal, rapidly rising blood sugar levels give more energy. An hour or two later, when blood sugar levels fall, energy levels decline as well. This drop in blood sugar can lead to drowsiness, lack of concentration and increased appetite – which often result in low productivity and food cravings.

Foods rich in resistant starch can help modulate these swings, especially if they replace foods high in glycemic carbohydrates. This can result in a feeling of more balanced energy throughout the day.

The Positive Effects

Eating foods with natural resistant starch helps balance your energy in the hours following a meal, mitigating a drop in blood sugar because:

- It **lowers the glycemic and insulin response** of foods when it is used to replace flour.
- It has a **sustained energy release**: It releases part of its energy in the small intestine as glucose and part of its energy in the large intestine many hours later as fermentation by-products, such as acetate. While glucose is the exclusive energy source for the brain, acetate is used as an energy source in muscle and fat tissue.

[1] © HealthFocus Int'l 2007
[2] The Whole Grains Council, www.wholegrainscouncil.org.

Resistant Starch & Blood Sugar

"Good blood glucose control is the single most important factor in preventing the chronic health complications associated with diabetes, and current research suggests that controlling blood glucose levels after meals is an important component of overall blood glucose management. The most common method used to minimize blood glucose levels after meals is to limit the amount of carbohydrate consumed at meals and snacks and to match the amount of carbohydrate eaten with a person's medication and activity level. For many people, however, limiting the amount of carbohydrate in the diet can be difficult. This is where foods made with resistant starch may be helpful."

Belinda O'Connell, M.S. R.D., L.D.
Diabetes Self-Management magazine

The Stats[1]

- 47 million Americans (23.7%) have metabolic syndrome. Mexican-Americans have the highest incidence at 31.9%.
- Insulin resistance and abdominal obesity are the underlying risk factors of metabolic syndrome.
- 20.1 million Americans (9.6%) have diabetes
- 14.7 million Americans (7.0%) have pre-diabetes

The Role of Resistant Starch

There is no doubt that diabetics benefit from controlling the release of glucose from foods.[2] Recent research has shown that elevated blood glucose can also have health implications for non-diabetic individuals as well.

Metabolic syndrome, a combination of disorders characterized by elevated insulin levels (linked to the glucose concentration in the blood stream), elevated blood triglycerides, low HDL cholesterol, high blood pressure and overweight, is a growing problem – particularly in developing economies. Insulin resistance and central adiposity are dominant underlying risk factors for this syndrome.

Resistant starch in foods helps to maintain healthy blood sugar levels in healthy individuals. It can also help diabetics manage their blood sugar levels.

The Positive Effects

Natural resistant starch helps maintain healthy blood sugar levels by:

- **Lowering the glycemic** (blood sugar) **and insulin response** of foods when it replaces flour or other digestible carbohydrates in foods.
- **Increasing insulin sensitivity** in healthy people and in individuals with diabetes[3]
- **Decreasing the glycemic and/or insulin response of the next meal**[4]

[1] "Heart Disease and Stroke Statistics – 2006 Update", American Heart Association.
[2] Brand – Miller J et al "The New Glucose Revolution: 3rd Ed. 2002
[3] Robertson, 2003 (Diabetologia), Robertson, 2005 (American Journal of Clinical Nutrition), Zhang, 2007 (Chinese Journal of Preventive Medicine)
[4] Bringheti, 2006 (American Journal of Clinical Nutrition), Robertson, 2003 (Diabetologia), Robertson, 2005 (American Journal of Clinical Nutrition) and Behall, 1989 (American Journal of Clinical Nutrition).

Select Studies on Resistant Starch

There is substantial research on the health benefits of natural RS2 resistant starch, including more than 160 peer-reviewed nutritional studies carried out over the last 15 years, demonstrating benefits in weight management, blood sugar management, energy management, and digestive health.

Of these nutritional studies, more than 50 studies in humans using high amylose maize show that RS2 starches (e.g., Hi-maize resistant starch) contribute specific health benefits. This data provides confidence in the benefits be obtained through consuming RS2 resistant starches.

Today, surveys show clearly that consumers seek these specific health benefits (see Consumer section of this conference book). Americans are becoming more and more aware of the importance of dietary fiber – and of their own personal fiber gaps – yet they have been turned-off by early-stage fiber products that didn't deliver on taste.

New research indicates that consumers are most motivated to improve their fiber intake when the benefits of fiber (energy management, weight management and digestive health) are effectively communicated. The combination of these health advantages along with the significantly improved quality of commercial products made with natural resistant starch should bring consumers closer to closing the fiber gap while at least doubling their current resistant starch intakes.

The volume and findings of research on natural resistant starch are compelling. To cite just a few select studies:

1. Natural resistant starch can assist in weight management.

A 2007 study by Dr. Wen-qing Zhang at the Chinese Center for Disease Control and Prevention in Beijing, China found that eating foods made with 30 grams of Hi-maize resistant starch per day decreased the Body Mass Index of 40 diabetics.

Numerous studies have also found significant reductions in body fat in animal models (Keenan, Pawlak and Zhou). At least two mechanisms may be contributing: (1) A clinical study (funded by NIH) by Dr. Janine Higgins at the University of Colorado found that eating just one meal containing 5 grams of Hi-maize resistant starch can increase an individual's ability to burn fat by 20-25%. (2) Animal studies have also found that dietary consumption of Hi-maize increases the production of the satiety hormones GLP-1 and PYY. (Keenan 2006 and Keenan NAASO, Zhou 2007).

[Wen-qing Zhang, Hong-wei Wang, Yui-ming Zhang, Yue-xin Yang: Effects of resistant starch on insulin resistance of type 2 diabetes mellitus patients. *Chinese Journal of Preventive Medicine* 2007: 41(2):101-104.

Higgins JA, Higbee DR, Donahoo WT, Brown IL, Bell ML, Bessesen DH, 2004. Resistant starch consumption promotes lipid oxidation. *Nutrition & Metabolism* 1:8.

Keenan MJ, Zhou J, McCutcheon KL, Raggio AM, Bateman HG, Todd E, Jones CK, Tulley RT, Melton S, Martin RJ, Hegsted M. 2006. Effects of resistant starch, a non-digestible fermentable fiber, on reducing body fat. *Obesity* 14(9): 1523-1534.

Keenan, M.J., Zhou, J., Rattio, A.M., McCutcheon, K.L., Newman, S.S., Tulley, R.T., Martin, R.J., Brown, I., Birkett, A., Hegsted, M. Preliminary microarray analysis of genes from cecal cells of resistant starch fed rats NAASO, The Obesity Society, October 20-24, 2006.

Zhou, J, Keenan MJ, Raggio AM, Tripathy S, Shen L, McCutcheon KL, Hegsted M, Tulley RT, Martin RJ. Feeding resistant starch maintains elevated plasma levels of GLP-1 and PYY throughout the day and is associated with decreased body fat in rats. The FASEB Journal 2007;21:352.3.

Pawlak DB, Kusher JA, and Ludwig DS. 2004. Effects of dietary glycaemic index on adiposity, glucose homeostasis, and plasma lipids in animals. *Lancet,* 364:778-85.]

2. Natural resistant starch increases insulin sensitivity.

Dr. Denise Robertson and her colleagues at the Oxford Centre for Diabetes, Endocrinology and Metabolism, University of Oxford, UK showed that natural resistant starch (RS2) consumption increased insulin sensitivity in noninsulin-resistant subjects by changing both adipose tissue and skeletal muscle metabolism.

Dr. Wen-qing Zhang and his colleagues at the Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention in Beijing, China, found that Hi-maize RS2 resistant starch increased insulin sensitivity in patients with Type 2 diabetes.

[M Denise Robertson, Alex S Bickerton, A Louise Dennis, Hubert Vidal and Keith N Frayn: Insulin-sensitizing effects of dietary resistant starch and effects on skeletal muscle and adipose tissue metabolism. The *American Journal of Clinical Nutrition* 2005;82:559–67.

Wen-qing Zhang, Hong-wei Wang, Yui-ming Zhang, Yue-xin Yang: Effects of resistant starch on insulin resistance of type 2 diabetes mellitus patients. *Chinese Journal of Preventive Medicine* 2007: 41(2):101-104.]

3. Natural resistant starch lowers the impact on glycemic and insulin response of foods. It also lowers the glycemic response of the next meal.

Natural resistant starch reduces the impact on blood glucose and insulin when it replaces flour in foods. One study, led by Dr. Kay Behall and colleagues at the Beltsville Human Nutrition Research Center at the USDA, found that consumption of a moderate amount of natural RS2 resistant starch from high amylose corn lowers the glucose and insulin responses of both normal and overweight women by 24% and 38% respectively. She also found synergies when the soluble fiber beta-glucan from oats was added to the resistant starch in the diet: 33% and 59% reductions in Area under the Curve measurements of blood glucose and insulin levels, respectively.

Another study by Dr. Furio Brighenti and his colleagues at the University of Parma, the University of Verona and the University of Milan, Italy found that RS2 from high amylose corn significantly reduced the glycemic and insulin response when incorporated into sponge cake. They also found that the fermentation of resistant starch independently improved postprandial glycemic responses of the subsequent meal.

[Behall KM, Hallfirsch JG, Scholfield DJ, Liljeberg-Elmstahl HGM. 2006 Consumption of both resistant starch and beta-glucan improves post prandial plasma glucose and insulin in women. *Diabetes Care*. 29:976-981.

Brighenti F, Benini L, Del Rio D, Casiraghi D, Pellegrini N, Spazzina F, Jenkins DJA., Vantini I. 2006. Colonic fermentation of indigestible carbohydrates contributes to the second-meal effect *Am J Clin Nutr.* 83:817-822.]

4. Natural resistant starch increases natural defenses against bowel cancer.

Led by Dr. Shusuke Toden at CSIRO and the University of Adelaide in Australia and published in *Cancer Biology & Therapy* and *British Journal of Nutrition* in 2007, these animal studies demonstrated that Hi-maize resistant starch protected colonic cells from genetic damage induced by high protein diets. It also prevented thinning of the protective mucous layer, a feature in ulcerative colitis and a biomarker for colon cancer.

Led by Dr. Richard Le Leu at Flinders University in South Australia, and published in *Carcinogenesis* in 2006, this animal study demonstrated that Hi-maize protected against intestinal tumorigenesis and prevented the harmful fermentation effects of indigestible protein.

These studies also confirmed that Hi-maize positively influenced additional colonic biomarkers for health. It reduced large intestinal pH, and increased short-chain fatty acids (SCFAs), including butyrate. Butyrate is the preferred energy source for healthy colon cells and is important for colon health.

[Toden S, Bird AR, Topping DL, Conlon MA. Dose-dependent reduction of dietary protein-induced colonocyte DNA damage by resistant starch in rats correlates more highly with caecal butyrate than with other short chain fatty acids. *Cancer Biology & Therapy,* February 2007, 6:2: e1-e6.

Toden S, Bird AR, Topping DL, Conlon MA. Differential effects of dietary whey, casein and soya on colonic DNA damage and large bowel SCFA in rats fed low and high in resistant starch. *British Journal of Nutrition* Mar 2007;97(3):535-43.

Le Leu RK, Brown IL, Hu Y, Morita T, Esterman A, Young GP. Effect of dietary resistant starch and protein on colonic fermentation and intestinal tumourigenesis in rats. *Carcinogenesis,* February 2007;28(2): 240-5.]

5. Natural resistant starch lowers calories.

RS-rich starch may be useful for weight management because it doesn't yield the full 4 kilocalories per gram, but yields about 68% (in humans) of its potential energy: between 2 - 3 kcal/gram. The energy is yielded partially through the digestion of its regular starch portion as well as through the fermentation of the RS-rich portion in the large intestine. Findings are from a study led by Kay Behall and Juliette Howe at the Diet and Human Performance Laboratory, Beltsville Human Nutrition Research Center, US Department of Agriculture, Beltsville, MD.

[Behall, KM, Howe JC. Resistant starch as energy. *The Journal of the American College of Nutrition* 1996;15(3):248-54.]

Overview of Human Studies With Resistant Starch

The more than 160 studies on the benefits of RS2 resistant starch from high amylose corn include *in vitro* models and animal models as well as more than 50 human clinical trials. Epidemiological studies are supportive, as they have correlated starch consumption with reduced risk of colorectal conditions.

Animal and *in vitro* models are valuable, as they provide a wealth of information, including mechanisms. However, human clinical trials are the most valuable in determining the physiological benefits of this type of resistant starch in humans.

The benefits of resistant starch are attributed to both the reduced glycemic and insulin response within the small intestine, and to the fermentation effects within the large intestine. While all dietary fibers decrease the glycemic and insulin response when they substitute for digestible carbohydrates, the fermentation effects distinguish resistant starch from other types of dietary fiber. The fermentation of natural resistant starch promotes a healthy colon via multiple mechanisms. Clinical trials have also shown that it significantly improves metabolism: *i.e.,* it increases insulin sensitivity, and increases fat burning.

Summary of relevant human studies with natural resistant starch (RS2):

- 23 published studies have shown beneficial effects of RS2 from high amylose corn on **glucose and/or insulin response**. When substituted for flour, it lowers the glycemic and/or insulin response of foods in a dose-dependent manner. (Anderson, AJCN 2002; Behall, AJCN 1988 - reduced peak; Behall, AJCN, 1989 - significant reduction within first hour; Behall & Howe, AJCN 1995; Behall & Hallfrisch, EJCN, 2002; Behall & Scholfield, CC, 2005; Behall, DC 2006; Behall, NR 2006; Brighenti, AJCN 2006; Brown, FA 1995; Giacco, DNM 1998; Granfeldt, JN 1995; Hoebler, EJCN 1999; Hospers, JFS 1996 - significant reduction within first hour; Howe, JN 1996; Krezowski, DC 1987; Noakes, AJCN 1996; Olesen, EJCN 1994; Reader, JADA 2002; van Amelsvoort & Weststrate, AJCN 1992; Vonk, AJCN 2000; Weststrate & van Amelsvoort, AJCN 1993; Zhang, CJPM 2007)

- 3 studies have shown **increased insulin sensitivity** in healthy people as well as in individuals with diabetes. (Robertson, D 2003; Robertson, AJCN 2005; Zhang, CJPM 2007)

- 2 published studies have shown beneficial effects on outcomes relevant to **weight management and metabolism**. One study showed increased lipid oxidation fat burning (Higgins, NM 2004), while the other study demonstrated increased satiety in the hours following a meal. (van Amelsvoort, AJCN 1992)

- 13 published studies have shown **beneficial effects on biomarkers for colon health** such as the production of short-chain fatty acids, lower pH, lower concentrations of ammonia and phenolics, decreased bile acids and increased fecal weight. (Alles, AJCN 1997; Birkett, AJCN 1996; Grubben, 2001; Heijnen, 1996; Heijnen, AJCN 1998; Hylla, AJCN 1998; Jenkins, 1998; Muir, AJCN 2004; Noakes, AJCN 1996; Phillips, AJCN 1995; Silvester, NC 1997; van Munster, DDS 1994; Wacker, CEBP 2002)

- 2 published studies have shown **reduced duration and severity of diarrhea** in adults and children when Hi-maize was added to oral rehydration solutions. (Rangupathy, JPGN 2006; Ramakrishna, NEJM 2000)

References for Animal Studies:

Brown I, Warhurst M, Arcot J, Playne M, Illman RJ, Topping DL, "Fecal numbers of bifidobacteria are higher in pigs fed Bifidobacterium longum with a high amylose cornstarch than with a low amylose cornstarch" *The Journal of Nutrition* (1997) 127:1822-1827.

Higgins, J.A., Brown, M.A., Storlien, L.H. Consumption of resistant starch decreases postprandial lipogenesis in white adipose tissue of the rat. *Nutrition Journal* (2006) 5:25.

Keenan, M.J., Zhou, J., McCutcheon, K.L., Raggio, A.M., Bateman, H.G., Todd, E., Jones, C.K., Tulley, R.T., Melton, S., Martin, R.J., Hegsted, M. Effects of resistant starch, a non-digestible fermentable fiber, on reducing body fat. *Obesity* (2006), 14(9):1523-1534.

Keenan, M.J., Zhou, J., Rattio, A.M., McCutcheon, K.L., Newman, S.S., Tulley, R.T., Martin, R.J., Brown, I., Birkett, A., Hegsted, M. Preliminary microarray analysis of genes from cecal cells of resistant starch fed rats**.** NAASO, The Obesity Society, October 20-24, 2006.

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Le Leu, R.K., Brown, I.L., Hu, Y., Morita, T., Esterman, A., Young, G.P. Effect of dietary resistant starch and protein on colonic fermentation and intestinal tumourigenesis in rats. *Carcinogenesis* (2007), 28(2):240-5.

Moreau, N.M., Champ, M.M., Goupry, S.M., Le Bizec, B.J., Krempf, M., Nguyen, P.G., Dumon, H.J., Martin, L.J. Resistant starch modulates in vivo colonic butyrate uptake and its oxidation in rats with dextran sulfate sodium-induced colitis. *Journal of Nutrition* (2004), 134:493-500.

Morita, T., Tanabe, H., Sugiyama, K., Kasaoka, S., Kiriyama, S. Dietary resistant starch alters the characteristics of colonic mucosa and exerts a protective effect on trinitrobenzene sulfonic acid-induced colitis in rats*. Bioscience, Biotechnology & Biochemistry* (2004), 68 10:2155-2164.

Morita, T., Tanabe, H., Takahashi, K., Sugiyama, K. Ingestion of resistant starch protects endotoxin influx from the intestinal tract and reduces D-galactosamine-induced liver injury in rats. *Journal of Gastroenterology and Hepatology* (2004), 19:303-313.

Pawlak, D.B., Bryson, J.M., Denyer, G.S., Brand-Miller, J.C. High glycemic index starch promotes hypersecretion of insulin and higher body fat in rats without affecting insulin sensitivity. *Journal of Nutrition* (2001), 131:99-104.

Pawlak, D.B., Kushner, J.A., Ludwig, D.S. Effects of dietary glycaemic index on adiposity, glucose homeostasis, and plasma lipids in animals. *The Lancet* (2004), 364:778-785.

Subramanya, S., Ramakrishna, B.S., Binder.H.J., Farthing, M.J., Young, G.P., Evaluation of oral rehydration solution by whole-gut perfusion in rats: effect of osmolarity, sodium concentration and resistant starch. *Journal of Pediatric Gastroenterology and Nutrition* (2006) 42(5):568-575.

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Toden, S., Bird, A.R., Topping, D.L., Conlon, M.A., Differential effects of dietary whey, casein and soya on colonic DNA damage and large bowel SCFA in rats fed diets low and high in resistant starch. *British Journal of Nutrition* (2007) Mar 97(3): 535-43.

Toden, S., Bird, A.R., Topping D.L., Conlon, M.A., Resistant starch prevents colonic DNA damage induced by high dietary cooked red meat or casein in rats. *Cancer Biology & Therapy* (2006) Mar; 5(3):267-72.

Zhou, J., Hegsted, M., McCutcheon, K.L., Keenan, M.J., Xi, X., Raggio, A.M., Martin, R.J. Peptide YY and proglucagon mRNA expression patterns and regulation in the gut. *Obesity* (2006), 14 (4):683-689.

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Alles MS, Katan MB, Salemans JMJI, Van Laere KMJ, Gerichhausen MJW, Rozendaal MJ, Nagengast FM. Bacterial fermentation of fructooligosaccharides and resistant starch in patients with an ileal pouch – anal anastomosis. *The American Journal of Clinical Nutrition* 1997;66:1286-92.

Anderson GH, Catherine NLA, Woodend DM, Wolever TMS. Inverse association between the effect of carbohydrates on blood glucose and subsequent short-term food intake in young men. *The American Journal of Clinical Nutrition* 2002;76:1023-30.

Behall KM, Scholfield DJ, and Canary J. Effect of starch structure on glucose and insulin responses in adults. *The American Journal of Clinical Nutrition* 1988; 47(3): 428-32.

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