CarboStar™ Development and Validation:
A Method to Make Starch Function Like Dietary Fiber

Saatwic Foods
Health • Wellness • Nutrition

August 2007

Saatwic Foods 9003 Overlook Boulevard Brentwood, TN 37027 U.S.A. +1 615-372-7462 www.saatwic.com

The CarboStar™ Method Validation:
A Method to Make Starch Function Like Dietary Fiber

Abstract

Carbohydrates (starch in particular) are the major source of energy the human body utilizes from the foods it consumes. Starch needs to be gelatinized (cooked) in order to be processed by the body's digestive system. Cooking enables the starch cell to absorb moisture, enlarge, and burst open to release its energy-rich contents. Glucose exists inside the starch granule as amylose (a linear polymer) and amylopectin (a branched chain polymer) in a crystalline form. The digestive process releases glucose from starch for utilization by the body for its energy needs. Saatwic Foods has discovered glucose release can be regulated by controlling the bursting of starch cells through the use of plant extracts. Products made from flour (corn, wheat, potato, and/or rice) and a small amount of GRAS-classified plant extracts had strengthened starch cells that allowed for a controlled rupture and subsequent calorie release. Saatwic Foods has patented this process as the CarboStar Method. *In vitro* studies showed a 50% reduction of calories from carbohydrates in CarboStar product compared to Control. NLEA analysis showed CarboStar product contained 56% more fiber than Control. Glycemic index testing confirmed CarboStar product was low in glycemic index (GI) and glycemic load (GL). A trained hedonic panel preferred the taste and texture of the CarboStar product over Control prepared under a variety of conditions, including extended warming table exposure, soup canning, and retort packing. These results were further validated with instrumental evaluation.

Introduction

Obesity and diabetes are now recognized to be at epidemic proportions in the United States. The Centers for Disease Control and Prevention (CDC) estimates that 60% of American adults (118 million) are overweight; 30% (59 million) American adults are clinically obese. Overweight adults and children face increased risks of chronic diseases, including diabetes and heart disease. According to the American Diabetes Association, 18.2 million Americans suffer from Type 1 and Type 2 diabetes.

The importance of a healthful eating pattern has been a consistent message from the American Dietetic Association (ADA), but the evolution of American attitudes and behaviors have made adherence to this advice increasingly difficult. "Not wanting to give up my favorite foods" was the most common reason given by those who said they are doing "the same" or "less" than two years ago to improve dietary habits. Conversely, nine out of ten people state that diet and nutrition are important to them. The attitude of "I need to eat better" has been prevalent in America since the 1980s. Numerous diets and fads have appeared and disappeared over the past 26 years. Low sugar gave way to low fat, which then led to low carb. For each of these diets and fads, food manufacturers created products to meet stated consumer demand for healthier foods. However, most of these products (like Tab cola, Oscar Mayer Fat-Free Hotdogs, Mueller's Reduced Carb Pasta) failed in the marketplace because consumers were unwilling to sacrifice taste and enjoyment for health and wellness benefits.

The challenge faced by food manufacturers is deceptively simple: increase the nutritional value of foods people know and enjoy today without negatively impacting taste and enjoyment.

The solution for food manufacturers to quickly revamp their product line to be aligned with today's focus on health and wellness through nutrition is to use the CarboStar Method.

The CarboStar Method is a patented processing method that enables conventional starch to function like dietary fiber. CarboStar works by using GRAS-classified plant extracts that interact with starch cells to strengthen their cell walls, thus impeding the release of its calorie-rich contents. This method enables manufacturers to use native starches and conventional manufacturing methods to make starch-based foods with an improved nutritional profile. Specifically, improved nutrition means:

- More fiber
- Fewer calories
- Slow digesting (burning) carbohydrate

The CarboStar Method can be applied to any processed carbohydrate, including wheat, potato, corn, and rice. Examples of foods in this category include: pasta (including noodles for soups), tortilla chips, pretzels, baked potato crisps, pizza crusts, breads, crackers, biscuits, and breakfast cereals. Both regular and whole grain foods can be made using the CarboStar Method.

Saatwic Foods has exhaustively tested and confirmed that the CarboStar Method controls starch cell rupture and regulates energy availability. Product evaluations show a 56% increase in dietary fiber, a 50% reduction of calories from carbohydrates, and a 35% reduction in glycemic load without any alteration of taste, safety concerns, or digestive abnormalities.

The CarboStar Method also enhances the resilience of starch-based foods. CarboStar products, such as pasta, resist overcooking (even after 20 minutes of boiling, it maintains an *al dente* bite), can be reheated in a microwave without turning rubbery, maintain their shape and texture even after several hours on a warming table, and remain firm in applications such as canned soups, frozen soups, and retort-packaged soups. The CarboStar Method can enable food manufacturers to use whole grain pastas in its soups and other packaged meals. In addition, the CarboStar Method eliminates the need for egg whites, modified starches, or other proteins during soup and frozen pasta manufacture, thus reducing direct material costs.

Product evaluations described within this document were conducted on pasta (enriched semolina elbow macaroni) made using the CarboStar Method. The Control product used in all evaluations was made from the same crop of semolina and manufactured at the same facility. The following evaluations were conducted:

1. Cooking loss
2. Product yield
3. Animal trial
4. Human trial
5. a-amylase
6. Glycemic index and glycemic load
7. Optical microscopy
8. Scanning electron microscopy
9. Starch isolation
10. Label claim analysis
11. Taste and texture

1. Cooking loss

Total solids (% cooking loss) lost in cooking water determined under standardized conditions is an industry-standard quality control test of pasta quality. Pasta with an elevated level of cooking loss is often deemed unacceptable by consumers – it is described as “soft,” “mushy,” and “sticky.” The magnitude of cooking loss (and thus the region of “acceptable” to “unacceptable”) varies with pasta cut.

In this study, cooking loss was determined by following the AACC 66-50 Method for determining Pasta and Noodle Cooking Quality – Firmness. Cooking times were found to be 10 minutes for Control and 14 minutes for Test. Control had a cooking loss of 7.2%; Test had a cooking loss of 8.2%. The nominal range of cooking loss for high-quality elbow macaroni is 7-10%; both Control and Test product were within this range. This result is presented in Figure 1

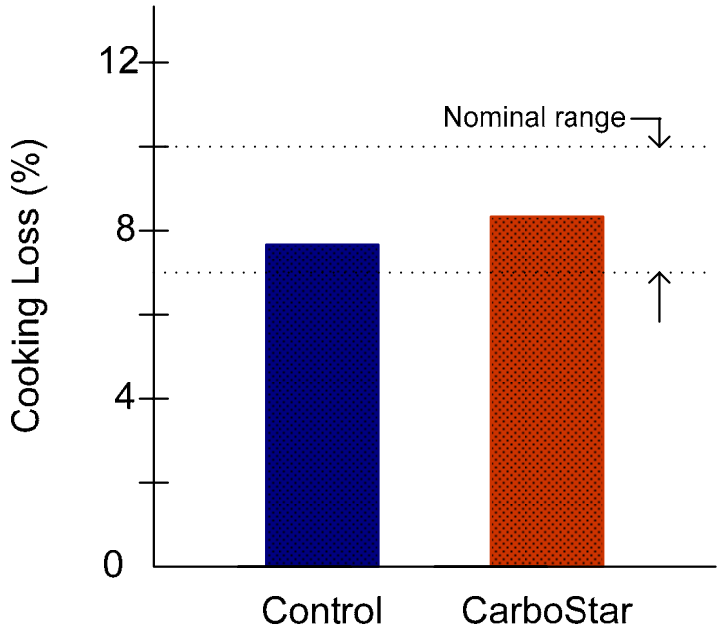

Figure 1: Cooking Loss

2. Product yield

Product yield refers to the mass ratio of cooked pasta to uncooked pasta. Product yield is directly proportional to increase in the pasta size. The higher the product yield, the less dry product is required to fill a given volume with cooked pasta.

In this study, product yield was determined by following the AACC 66-50 Method for determining Pasta and Noodle Cooking Quality – Firmness. Using cooking times of 9 minutes for Control and 14 minutes for Test, 50g of CarboStar product cooked up to 203g while 50g of Control cooked up to only 152g. This result is presented below in Figure 2.

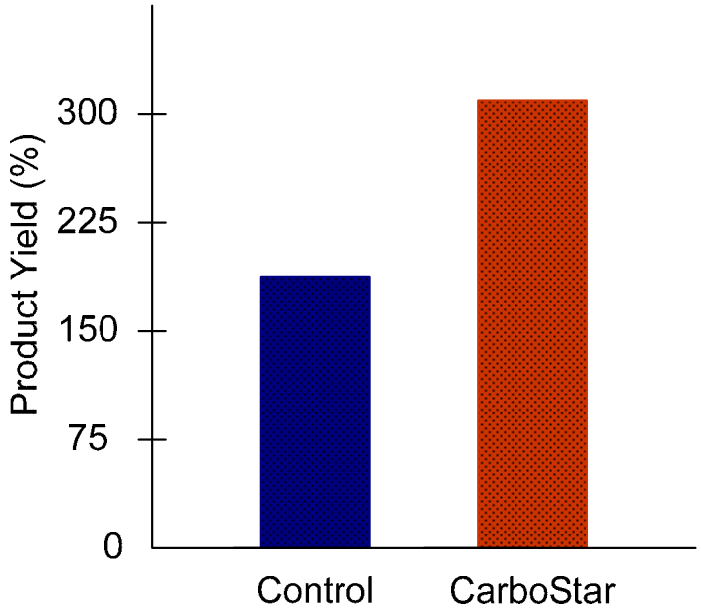

Figure 2: Product Yield

This result indicates that about *25% less dry pasta will be required to meet the noodle volume requirements for each unit of finished product.* The reduced quantity of raw materials required will yield additional ingredient cost savings.

3. Animal trial

A feeding trial was conducted to study the effect of the CarboStar Method in laboratory rats. This trial was conducted at the Department of Food and Animal Sciences at Alabama A&M University, Huntsville, Alabama. Five groups of rats were fed different varieties of food: AIN 93G diet (Control, standard rat feed formula), Control pasta – cooked, Control pasta – uncooked, CarboStar pasta – cooked, and CarboStar pasta – uncooked. Rats were fed the dietary treatment for a four-week period.

The rats that were fed the CarboStar pasta ingested greater quantities of feed than those rats fed Control pasta. Since the energy requirements of the rats were similar, this finding indicates that the energy availability per unit volume of CarboStar product is *less* than in the Control product.

The results of this study are presented below in Table 1. The column heading used in Table 1 are defined as follows:

Control:	AIN 93G diet	TP-UC:	CarboStar Pasta, Uncooked
CP-UC:	Control Pasta, Uncooked	TP-C:	CarboStar Pasta, Cooked
CP-C:	Control Pasta, Cooked		

Table 1: Feed consumption (g) for Fisher 344 male rats in the CarboStar feeding trial.

	Treatments				
Parameter	Control	CP-UC	CP-C	TP-UC	TP-C
Feed Consumption	111.7[a]	106.6[b]	101.6[b]	119.9[a]	114.9[a]

[a, b,] Values in the same row with different superscripts are significantly (P< 0.05) different (Tukey's Test), (SAS, 2004). SAS, (Version 6.12). Statistical Analysis Systems, Inc., Carey, NC.

4. Human trial

One subject who is a Type-2 diabetic participated in a double-blind study. In this study, the subject consumed meals of identical mass (on a dry basis) and preparation. One meal was made from Control product, the other from CarboStar product. Blood glucose levels were measured at 0, 30, 60, 90, and 120 minutes after the meal.

Control product resulted in a sharp increase in blood glucose level during the first 30 minutes after consumption. During the next 30 minutes, blood glucose level continued to increase, but at a significantly reduced rate. After 60 minutes, blood glucose level dropped sharply.

The blood glucose response from consumption of CarboStar product was significantly different. The blood glucose level rose consistently during the first *60 minutes* after consumption at a rate 50% less than that of Control; it continued to increase at a reduced rate for the subsequent 30 minute period. Blood glucose level began to fall only after 90 minutes.

The data from this study is presented below in Figure 3 and Table 2. These results demonstrate that products manufactured using the CarboStar Method will not cause a sudden spike in blood glucose levels and will provide energy over a longer period of time than conventional product.

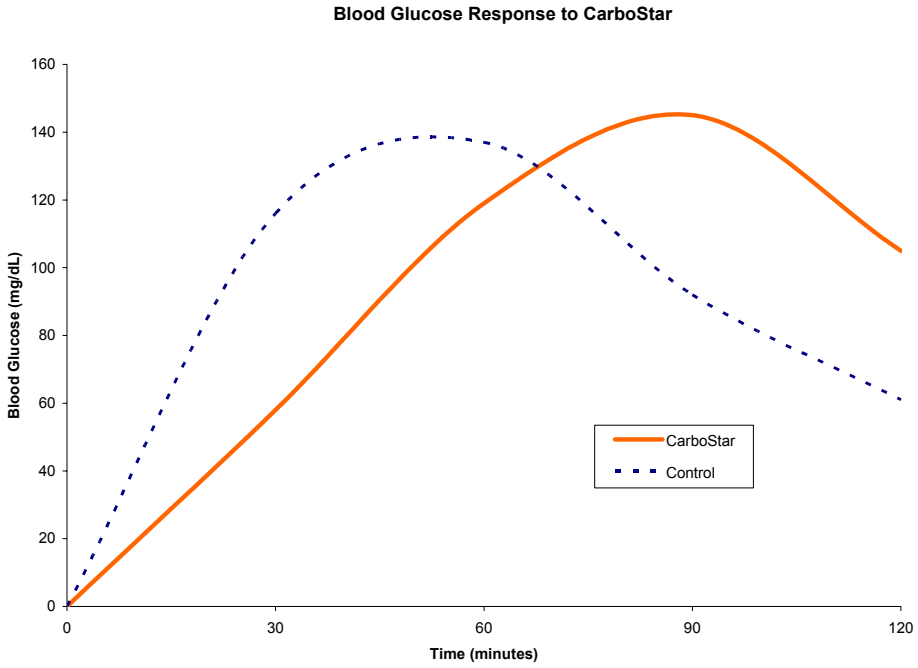

Figure 3: Graph of blood glucose response to Control and CarboStar product.

Table 2: Blood glucose response to Control and CarboStar product.

	Blood Glucose Level (mg/dL)	
Time	**CarboStar**	**Control**
0	0	0
30	58	116
60	119	137
90	145	92
120	105	61

5. α-amylase test

By strengthening the starch cell wall and impeding digestion, the CarboStar Method reduces calories from starch. Starch is digested by the enzyme alpha (α) amylase. Alpha amylase is a digestive enzyme classified as a saccharidase, an enzyme that processes polysaccharides. It is found in pancreatic juice and saliva. The primary product of α-amylase activity on gelatinized starch is maltose. The body's digestive process can be simulated by introducing α-amylase to food products and measuring the maltose produced. The quantity of maltose released provides a measure of the energy that would be made available for absorption by the body.

In this study, α-amylase was introduced to equal amounts of cooked Control and CarboStar product (on a dry mass basis). The quantity of maltose produced was measured using a spectrophotometer. Control product was used as the reference point. The test duration was 120 minutes.

At the end of two hours, the area under the CarboStar curve was 0.349 mg*hr; the area under the Control curve was 0.692 mg*hr. This result clearly shows that, on a dry mass basis, CarboStar product contains 50% fewer calories from carbohydrates than conventional product. This means that, using the same ingredients and manufacturing process it uses today, food manufacturers can make reduced calorie versions of their products that taste the same as their current products.

The results of this study are presented below in Figure 4.

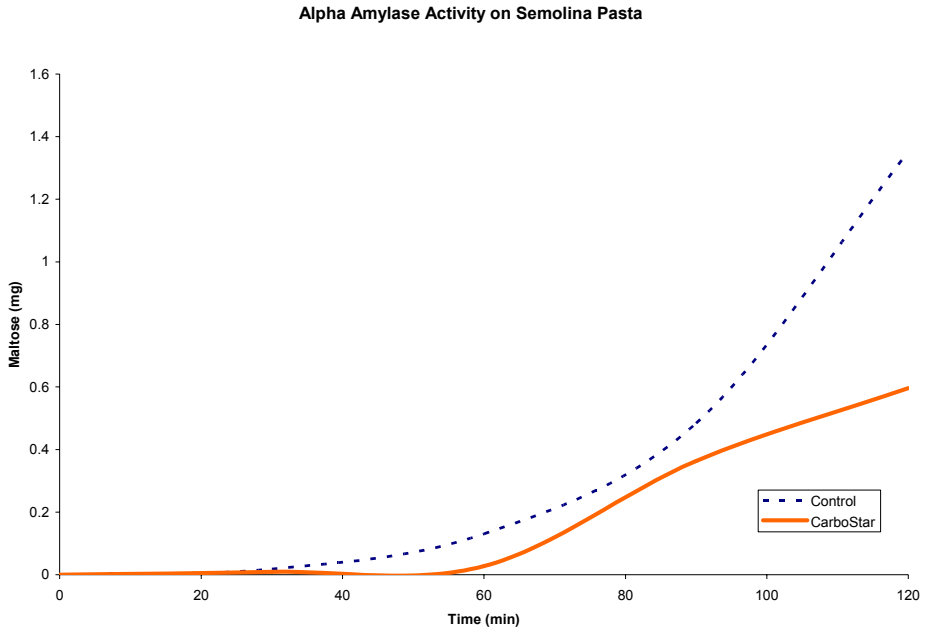

Figure 4: Graph of maltose production due to α-amylase activity on Control and CarboStar product.

6. Glycemic index and glycemic load

The CarboStar Method can reduce the glycemic impact of products that contain pasta. The glycemic index (GI) provides a measure of the rate at which a carbohydrate is digested (i.e. burned) within the body. The GI of a food is found by indexing the glycemic response of a fixed amount of available carbohydrate from a test food to the same amount of available carbohydrate from a reference food (such as glucose, GI value set to 100) consumed by the same subject. The blood glucose area after consumption of the test food is expressed as a percentage of the reference. Foods with high GI value contain carbohydrates that cause a significant rise in blood glucose levels, while foods with low GI value contain carbohydrates with much less impact. The lower the GI value of a food, the slower it is digested. Slow burning foods travel further down the digestive tract than foods that are quickly broken down. The slower rate of digestion of low GI foods enables them to provide energy over a longer period of time. Carbohydrates that are slow-burning provide longer lasting satiety, stamina, and allow the consumer to "feel satisfied" longer.

While the GI value is a helpful gauge, it does not always reveal the whole story when choosing which carbohydrate to eat. Researchers calculate and compare the GI value of foods based on identical portions delivering 50 grams of carbohydrate. Glycemic load, a rating based on GI and amount of carbohydrate eaten, is a better indicator. The GL of a food is calculated by multiplying its GI value by the amount of carbohydrate per serving and dividing by 100. This value reflects both the type and amount of dietary carbohydrate and is more practical for everyday use.[1, 2]

The digestion of slow and fast burning carbohydrates, and their effect on blood glucose levels, is illustrated below in Figure 5.[3]

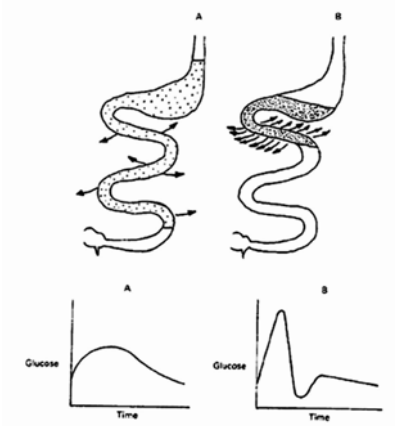

Figure 5: Schematic of the glycemic response of diets with a low (A) and high (B) glycemic load.

Glycemic index and glycemic load testing were conducted on CarboStar and Control pastas and Glycemic Index Laboratories, located in Toronto, Canada. These tests showed CarboStar pasta to be significantly lower in glycemic load. Dr. Alexandra Jenkins, a principal at Glycemic Index Laboratories and one of the pioneers of the glycemic index/glycemic load concept, followed its U.S. FDA and WHO-approved protocol for determining GI values and confirmed CarboStar macaroni had a low glycemic index value (GI<55)[4]. The results of these studies are presented below in Table 3.

[1] Brand-Miller et al, *The New Glucose Revolution*, Marlow and Company, 2003, p. 37.
[2] http://www.brighamandwomens.org/healtheweightforwomen/special_topics/intelihealth1002.aspx?subID=submenu10
[3] Jenkins D, Kendall C, Augustin L, Franceschi S, Hamidi M, Marchie A, Jenkins A, Axelsen M, "Glycemic index: overview an implications in health and disease," Am J Clin Nutr 2002;76(suppl):266S-73S.
[4] Brand-Miller et al, *The New Glucose Revolution*, Marlow and Company, 2003, p. 33.

Table 3: Glycemic index and glycemic load test results.

	Glycemic Index (GI)	Glycemic Load (GL)
CarboStar Macaroni	50	**15**
Control Macaroni	41	17
Standard Macaroni[5]	48	23

Key attribute

Noteworthy are three significant discoveries –
1) CarboStar and Standard macaroni had similar GI values, but their graphs were significantly different in shape. CarboStar macaroni produced a blood glucose curve that was not significantly different in peak height than Control. After the 60 minute mark, CarboStar sustained statistically significant elevated glucose levels longer than Control because of its slower rate of burn. CarboStar released energy over a longer period of time, which created a larger area under the blood glucose response curve than Control and Standard. Hence, the GI of CarboStar was higher than that of Control and Standard.

2) Standard Macaroni had a higher GI than Control because of the greater proportion of regrind in the former. "Regrind" is pasta product that has been shaped, dried, finely ground, and used to replace virgin flour in the manufacturing process. Conventional pasta (e.g. Standard Macaroni) typically contains about 10% regrind on a dry mass basis; "blue box" macaroni and cheese is made from 100% regrind. The Control macaroni used in this study contained no regrind. The regrind process damages the starch cells, making them easier to gelatinize and digest. Because Standard Macaroni cannot absorb as much water as CarboStar, the amount of dry CarboStar required to make one cooked portion size is *less* than that for Standard. Hence, the GL value for CarboStar is 35% lower than that of Standard.

3) CarboStar's glycemic load was significantly lower than that of Standard Macaroni. The similar GL values between Control and CarboStar macaroni can be attributed to the high quality of semolina used and the absence of regrind that conventional pasta contains, ranging from 10-100%.

According to Jenkins, the CarboStar Method slows the burning rate of carbohydrates significantly. Clearly, the CarboStar Method produces foods with longer lasting energy than conventional pasta. The effect of CarboStar, Control, and Standard on blood glucose levels are presented below in Figure 6.

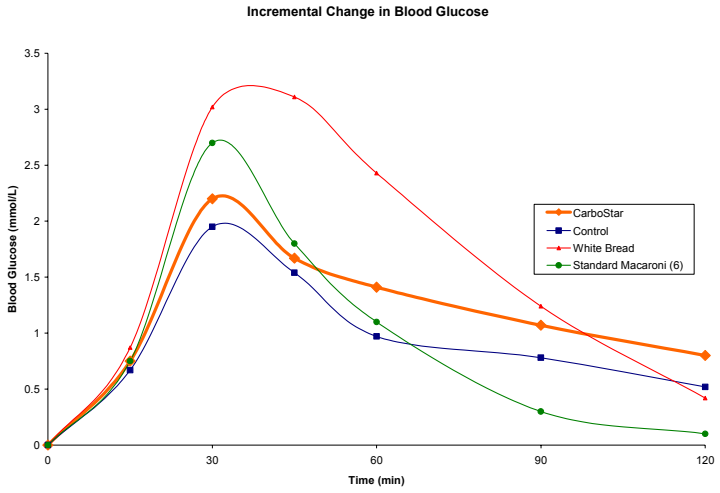

Figure 6: Comparison the incremental postprandial blood glucose response after CarboStar and Control product.

[5] Brand-Miller et al, *The New Glucose Revolution*, Marlow and Company, 2003, p. 313.
[6] Adopted from Brand-Miller et al, *The New Glucose Revolution*, Marlow and Company, 2003, p. 32.

7. Optical light microscopy

Optical light microscopy studies were conducted on the Control and CarboStar products. A sample of the test material from the α-amylase study (at t = 60 minutes) was transferred to a clean microscope slide and stained with iodine; the iodine marked intact starch cells as dark objects. Representative fields were recorded and are presented below. These observations show that the CarboStar sample contained a significantly higher number of intact starch cells compared to Control. Optical light microscopy photos for Control and CarboStar products are presented below in Figures 7 and 8, respectively. These figures confirm that the CarboStar Method delays the digestion (breakdown) of starch cells, thus regulating their energy release.

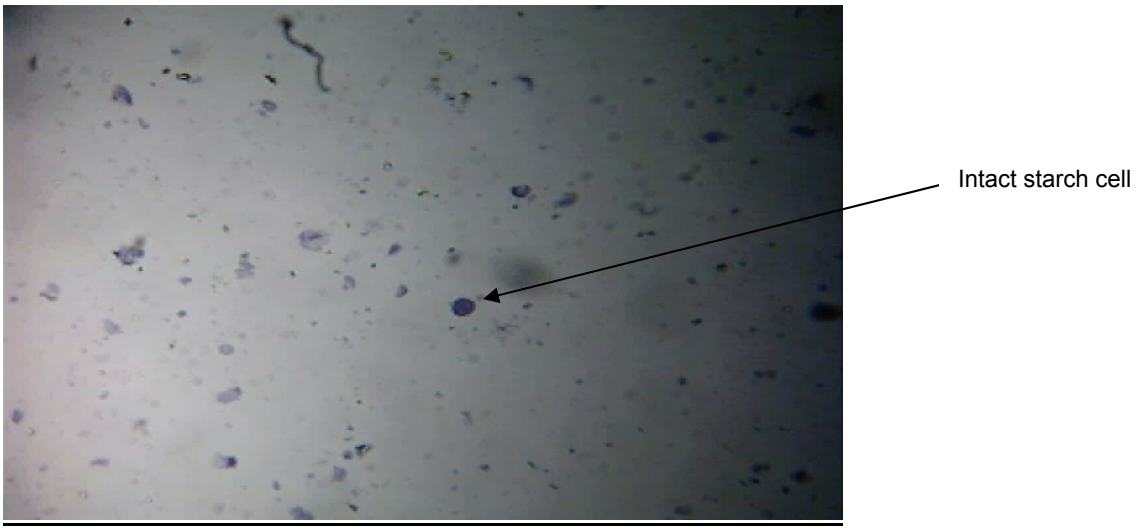

Figure 7: Control product with α-amylase treatment. Few intact starch cells exist.

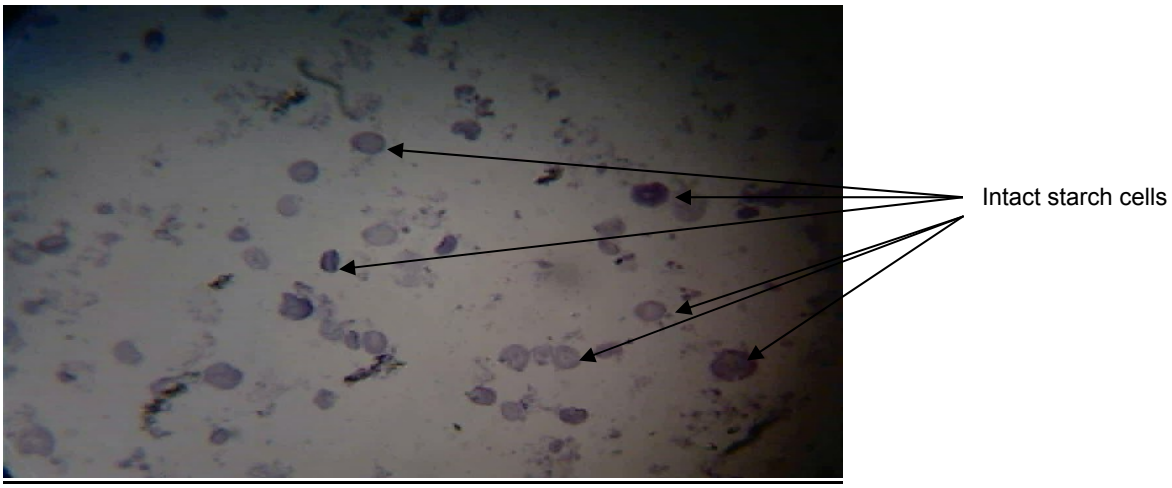

Figure 8: CarboStar product with α-amylase treatment. Several intact starch cells exist.

8. Scanning electron microscopy

Scanning electron microscopy studies were conducted on Control and CarboStar products. Samples were observed using a scanning electron microscope (SEM); representative fields were recorded and are presented below in Figure 9. The Control sample shows a protein matrix with many voids that once contained starch cells. Numerous intact starch cells are clearly visible in the CarboStar sample. This finding provides further evidence that the CarboStar Method strengthens starch cell walls, thus regulating the release of their energy.

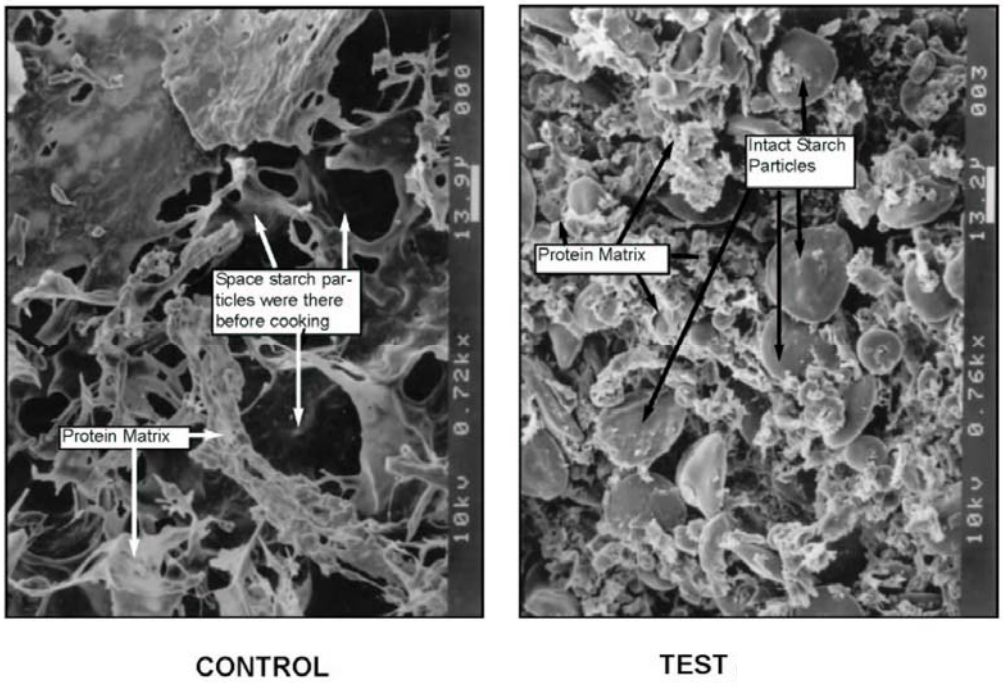

Figure 9: SEM photos of Control and CarboStar product samples.

9. Starch isolation

To better illustrate the mechanics of the CarboStar Method, processed starch was isolated and studied. Ten grams of Control and CarboStar elbows (dry) were soaked in 100 ml distilled water for three hours. Soaked macaroni was macerated with a pestle and mortar (triturated) with distilled water as needed. Cloudy supernatant fluid (containing released starch granules) was centrifuged and collected in a clean centrifuge tube. Collected starch was rinsed with three changes of distilled water. After the final rinse, the starch cake from the tube was transferred on to a clean paper and left to dry at room temperature for further analyses.

A drop of suspension of the isolated starch was placed on a clean microscope slide. One drop of iodine stain was added to each sample. A cover slip was applied to the slide and examined under a microscope with a digital camera attachment. Representative fields were photographed at the same magnification. Control and CarboStar photographs are presented below in Figures 10 and 11, respectively. As shown below, Control and Test starch suspensions were similar. The CarboStar sample contains far fewer hydrated (enlarged) starch cells than Control.

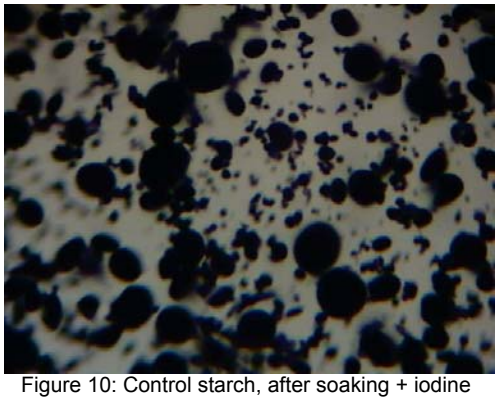

Figure 10: Control starch, after soaking + iodine

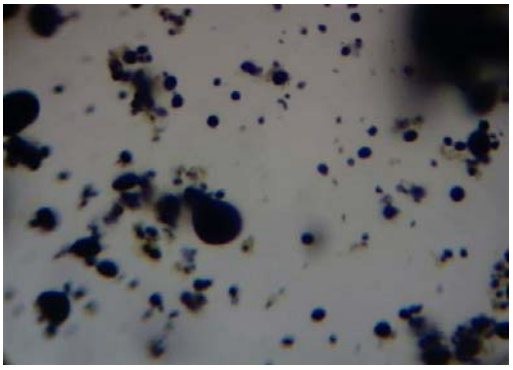

Figure 11: CarboStar starch, after soaking + iodine

To illustrate the effect of gelatinization (cooking), the slide was placed on top of a beaker that contained boiling distilled water for four minutes. The slide was then removed and allowed to cool. Control and CarboStar photographs are presented below in Figures 12 and 13, respectively.

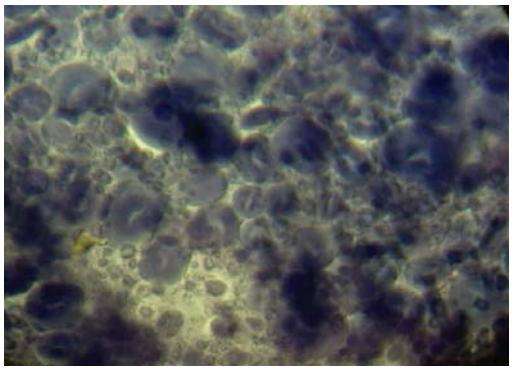

Figure 12: Control starch, after soaking, iodine, and steaming

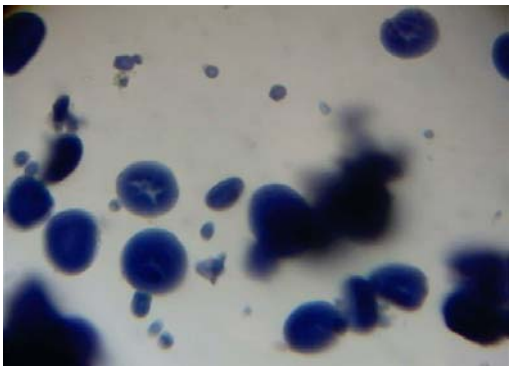

Figure 13: CarboStar starch, after soaking, iodine, and steaming

In Figure 12, almost all of the dark blue starch granules (intact starch cells) have disappeared. The light blue cells that remain are starch cells that have ruptured and released their contents (amylose and amylopectin); these ruptured cells are commonly referred to as “ghost cells.” Conversely, many of the starch cells in the CarboStar sample (Figure 13) are not ruptured. These findings conclusively demonstrate that the CarboStar Method strengthens the starch cell wall, thus impeding its breakdown and regulating energy release.

10. Label claim analysis

The CarboStar Method significantly increases the dietary fiber content of starch-based foodstuffs while all other nutritional components are comparable in taste and function. In accordance with the Nutrition Labeling and Education Act of 1990 (NLEA), manufacturers using CarboStar products may make nutrient content claims for the dietary fiber component and appropriate FDA-approved health claims. Control and CarboStar products were submitted to Covance Laboratories, Incorporated of Madison, Wisconsin for a NLEA analysis. The results of this analysis are presented below in Table 4.

Table 4: NLEA analysis results.

	CarboStar		**Control**	
	Analysis	*Units*	*Analysis*	*Units*
Calories	368	calories/100g	368	calories/100g
Calories from Fat	14.7	calories/100g	14.0	calories/100g
Total Fat	1.63	gm/100g	1.69	gm/100g
Saturated Fat	0.42	gm/100g	0.41	gm/100g
Cholesterol	0	mg	0	mg
Sodium	28.1	mg/100g	5.67	mg/100g
Total Carbohydrate	74.3	gm/100g	74.2	gm/100g
Dietary Fiber	4.2	gm/100g	2.7	gm/100g
Sugars	2.8	gm/100g	2.7	gm/100g
Protein	14.1	gm/100g	14.0	gm/100g

CarboStar products, in accordance with U.S. FDA regulations, may be labeled as “Good Source of Fiber,” as they contain ~ 10% of the recommended daily allowance (RDA) of dietary fiber. *The CarboStar Method can enable food manufacturers to make pasta from refined flour that contains similar levels of dietary fiber as pasta made from whole grain flour.* The proprietary blend of plant extracts used in the CarboStar Method contributes viscous dietary fiber that creates the feeling of satiety – so, consumers are satisfied and do not feel hungry for longer periods of time after a meal consisting of CarboStar products.

11. Taste and texture

The CarboStar Method increases the resilience of pasta products. Specifically, pasta made using the CarboStar Method maintains an *al dente* texture when subjected to the harsh conditions of retort packing, soup processing, frozen food processing, industrial foodservice. This attribute will enable food manufacturers to ***eliminate egg whites*** and other proteins from its product formulation, resulting in significant *ingredient cost savings.*

A trained sensory panel rated CarboStar pasta superior in taste, texture, aroma, and appearance in comparison with Control pasta using a 5-point Hedonic scale. The texture of the products was calibrated against quantitative measurements using a TA-XT2 Texture Analyzer (tests were conducted at the Department of Food Science and Technology at Cornell University). A Kramer Shear Cell fixture was used to measure the force required to cut through 100 grams of cooked pasta (both samples were cooked for 20 minutes). The results of these analyses are presented below in Table 5.

Table 5: TA-XT2 and trained sensory panel evaluation results.

Product	TA-XT2 Texture (Newtons/100g)	Trained Hedonic Panel Score*
Control	45.0	3.0
CarboStar	99.0	5.0

*5=Excellent; 4=Very Good; 3=Good; 2=Poor; 1=Very Poor

The TA-XT2 and hedonic evaluations found the CarboStar pasta to have “excellent” taste, texture, and mouthfeel; Control pasta did not perform as well.

In addition to producing superior-tasting pasta, the CarboStar Method enables pasta to be more resilient than conventional pastas. Pasta that was held at ambient, chilled, and elevated temperatures over a two hour period was tested following the American Association of Cereal Chemists (AACC) Method 66-50 (Pasta and Noodle Cooking Quality/Firmness); retort-packaged pasta was also tested using this method. The results of these tests are presented in the enclosed *Firmness* and *Retort Performance* technical specification sheets. In all cases, the CarboStar pasta was able to maintain its *al dente* texture long after the conventional pastas were unable to maintain their shape. These results show that pastas made using the CarboStar Method are well-suited for packaged soup applications. Since CarboStar pastas can be made without egg whites or other proteins, they are cost-effective to manufacture.

Numerous evaluations have confirmed that CarboStar products are well-received by the consumer palate. These evaluations included:

- Head to Head Comparison: CarboStar pasta was preferred over other "healthy" pastas and even conventional pastas in numerous taste tests.
- Secret Replacement: Over 400 student-athletes enjoyed CarboStar pasta when it was substituted for their regular pasta at their university dining facility.
- Youth Evaluation: Children have enjoyed our pasta, allowing those who cook for them to make favorite meals more nutritious.

Concluding Remarks and Next Steps

Food manufacturers can use the CarboStar Method to make pastas for its packaged meals that can maintain superior taste, texture, and mouthfeel while eliminating the need for egg whites or other proteins (resulting in significant ingredient cost savings). In addition, these pastas provide consumers with better nutrition: more fiber, fewer calories, and longer lasting energy. The CarboStar Method can enable food manufacturers to use whole grain and multi-grain pastas in its products.

At Saatwic Foods, we are very excited about your interest in the CarboStar Method. We welcome the opportunity to meet with you, present additional data, and provide product samples for your evaluation. For more information or to schedule a visit, please contact us.

About Saatwic Foods

The mission of Saatwic Foods is to offer consumers innovative ways to achieve good health and wellness through nutrition. We work with our clients to develop food products that taste good, are convenient to work with, have health benefits, and fit the clients' specific needs. *Saatwic* is a Sanskrit word that encompasses the elements of food, health and life. *Saatwic* describes food "that increases life, purity, strength, joy, cheerfulness, and well-being."

Saatwic Foods is a certified minority-owned business enterprise incorporated in the State of Tennessee.

For more information about Saatwic Foods and the CarboStar Method, please contact us.