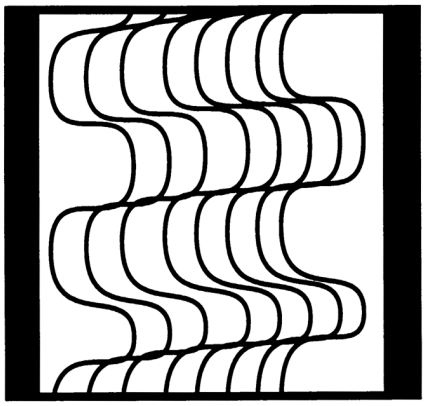

Development of a Dietary Fiber Gel for Calorie-Reduced Foods[1]

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Dietary fibers in the early days were referred to as roughage and consist of indigestible celluloses, hemicelluloses, lignin, gums, and mucilages. Trowell (1) and Burkitt and coworkers (2) were the pioneers relating the importance of fibers to gastrointestinal health. Today, it is well established that these insoluble fibers contribute to important gastrointestinal functions and that some of the soluble fibers can contribute to better blood composition.

Wheat bran is known to decrease transit time (3), whereas other fibers lower blood cholesterol (4). These fibers, particularly the corn and soy hulls, pass through the gastrointestinal tract without appreciable disruption of the rigid morphological cellular structures (5). Many milled cereal flours have been refined over the years to reduce the coarseness of these fibers in the gastrointestinal tract.

However, numerous studies have shown that some of the soluble fiber sources such as oat flours benefit health by lowering blood cholesterol (6–11), with more direct evidence being related to the soluble fiber, β-glucan (12–14). A patented method has introduced Oatrim to the marketplace as a source of soluble β-glucan and maltodextrins (15).

Preliminary studies on Oatrim have revealed that the biological properties are retained (16). Subsequent research by Hallfrisch and Behall and various others indicates that consuming Oatrim is associated with health benefits related to disease control, glucose and insulin responses, and weight control (17–20).

Z-Trim, as a new generation fat replacer, can be used for replacing fat and some of the glycemic materials (starches, sugars, and syrups) that are now widely used to replace fat in low-fat foods. The Z in Z-Trim refers to zero calories. It provides an aqueous gel fiber structure without taste and imparts a smooth texture. These gels have a smooth clean-cut-off texture unlike the stickiness and gumminess of some starch-syrup-gum combinations used in low-fat or fat-free foods. Z-Trim gels also provide insoluble fibers to be used separately or with other fibers such as Oatrim.

Processing

In the Z-Trim process, aqueous gel fibers are obtained from dietary fibers by complete disintegration of their cellular structures in a multistage alkaline shear process (21). Among the dietary fibers used in developing Z-Trim include those from oat, pea, corn, rice, soybean, and wheat. Corn bran, wheat bran, and oat hulls were obtained from Mountain Lake Specialty Ingredients Company (Mountain Lake, MN).

The specific conditions of treatment required in each of these stages varies depending on the nature of the starting substrate, other conditions used in the overall method of preparation, the specific method of drying, and whether any added hydrating substance is incorporated into the final product. Preferably, both stages are carried out at elevated temperatures. After at least the second stage of treatment, and preferably after both stages, the solids are separated from the liquids and the recovered insolubles are carried forward to the next processing step. The first-stage separation is designed to remove components that would tend to interfere with the second-stage treatment, and the second-stage separation is intended to isolate and recover the gel product. The recovered gels are purified and dried.

In the first-stage treatment, the ground dietary fiber substrate is slurried with aqueous alkali (pH 9–14) at concentrations in the range of about 5–25%. The preferred alkalis for use herein are sodium and potassium hydroxide. The forces for physically disrupting the cellular structures at this stage can be provided by a variety of means, such as a colloid mill, blender, jet cooker, extruder, or autoclave, depending on the substrate, for shearing the fibrous material. The temperatures are in the range of 75–150°C for 1–60 min. This treatment breaks down the fibers into a slurry of soluble and insoluble components that are both highly colored. The separation is centrifuged and washed to remove color bodies.

The solids obtained from the final washing of the first-stage treatment are resuspended in water at about 15% solids content and are subjected to the second-stage shear treatment at pH 8–11. The second-stage treatment requires an oxidizing agent such as hydrogen peroxide at temperatures around 40–70°C with intensive shearing for approximately 20–120 min. The wet solids are centrifuged, and the solids are washed until pH drops to about 6–9. The wet gel is dried by any conventional means, including drum drying, spray

[1] Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable. All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap.

Publication no. W-1997-0408-03F.

drying, warm air tray drying, and freeze drying.

The dried products are readily dispersible in water and can be rehydrated to give high-viscosity gels. The dried material, as with other large biopolymers, will rehydrate more readily in the presence of a hydrophilic substance, particularly hydrophilic carbohydrates such as maltodextrins, starches, gums, hemicelluloses, sugars, and oat flour hydrolyzates. When in hydrated form, the gels are smooth-textured deformable bodies of about 25–50 μm. The textural qualities imparted by the gels or gel powders can be tailored by appropriate fiber source selection and by coprocessing of fibers from different sources.

Factors Affecting Viscosity and Hydration Capacity

Fiber Source. The dried powder can be rehydrated using various levels of shear for variations in gel smoothness and viscosity. Vigorous shear using a Premier Mill model 90 high-viscosity head produced a viscosity of 4,200 cP for a 3% Z-Trim corn fiber compared with 5 cP for the starting corn bran. The gel has no taste, smooth texture, and water holding capacity of 22% compared to 4% for the unmodified bran.

Z-Trim oat fiber prepared from the hulls and vigorous sheared using a Premier Mill model 90 high-viscosity head produced a viscosity of 1,270 cP for 3% solids compared with 3 cP for the starting ground oat hulls. An equal combination of the corn and oat gel solids produced a viscosity of 4,600 cP, higher than that of either gel alone. The hydration capacity of the untreated hulls was 5% in contrast to 14% for the oat fiber gel and 23% for the equal combined gels. Z-Trim oat fiber had slightly more particulated textural qualities probably most suited for ground meat applications.

Z-Trim wheat fiber prepared from bran and a 3% solids concentration vigorously sheared using a Premier Mill model 90 high-viscosity head gave a viscosity of 1,400 cP compared with 4 cP for the starting wheat bran. The gel had no taste, smooth texture, and water holding capacity of 18% compared with 5% for the unmodified bran.

Shear Time and Water Temperature. The influence of shear time and water temperature on the rehydration of a 3% spray dried Z-Trim corn fiber is shown in Table I. The time of shear using a Premier Mill model 90 high-viscosity head revealed an increase in viscosity from 9,400 to 12,600 cP by extending the shear time from 2.5 to 10 min at 25°C. Repeating the same experiment using 50°C water indicated only a modest increase in viscosity from 9,500 to 10,700 cP. There was not sufficient change in the hydration capacities, both staying between 24 and 26%. The untreated corn bran did not demonstrate dramatic change in viscosity with increased shear time.

The Z-Trim oat fiber prepared from a commercially purified oat fiber (Canadian Harvest) and vigorously sheared using a Premier Mill model 90 high-viscosity head produced a viscosity of 11,100 cP for 10% solids compared with 240 cP for the starting oat fiber and 84 cP for the ground oat hulls at 25°C. The hydration capacity of the oat fiber was 5% and the hulls at 4% in contrast to 8% for the Z-Trim oat fiber gel. These hydration values were the same at 50°C. At this temperature the viscosity of the Z-Trim oat fiber gel was 15,700 cP compared to the starting fiber of 400 cP.

Co-dried Products. Co-drying hydrophilic carbohydrates, Oatrim-5, and guar gum with Z-Trim corn fiber gave products that gave different viscosity and hydration capacities depending on the method of drying—drum or oven. Oven drying the corn fiber gel with Oatrim-5 showed increased viscosity compared with the control (Table II). The guar gum co-dried product, also oven dried, had only slightly increased viscosity. The hydration capacities of oven-dried products were lower than those of the drum-dried product.

Freeze-Thaw Stability. The Z-Trim gels without the addition of protective colloids show appreciable loss of viscosity during freeze-thaw cycling. Prior to the three freeze-thaw cycles, the 3% corn, wheat, or oat fiber gels were held in the frozen state for 24 hr before thawing. Corn fiber gels prepared from lyophilized samples showed an 84% drop in viscosity after three cycles compared with a 48% drop for gels prepared from samples that had not been lyophilized. Wheat fiber and oat fiber gels that had been rehydrated from lyophilized samples gave losses in viscosity of 98% for wheat and 90% for oat (Table III).

Fat Replacement Potential

The powder can be used in some applications by adding an appropriate amount of water to produce the desired gel, which can be used to replace fat on a volume-to-volume (or weight-to-weight) basis.

Z-Trim gel can be used for considerable reduction in calories depending on the amount of fat and carbohydrates replaced in food formulations. The gel has zero calories regardless of amount compared to 9 calories per gram of fat. For example, both a processed cheese spread and a ham spread formulated with Z-Trim contained 22 cal per 28-g serving. This compares with values around 35 and 80 cal per 28 g for fat-free and full-fat processed cheese products currently available in the market. Similarly, values around 30 and 70 cal per 28 g were found for fat-free and regular ham products. All of these commercial cheese and ham products contained less than 1 g of fiber per serving, whereas the

Table I. Influence of Shear Time and Water Temperature on the Rehydration of 3% Spray Dried Corn Fiber Gel

Shear Time (min)	Temp. (°C)	Viscosity, cP		Hydration Capacity, %	
		Corn Fiber Gel	Corn Bran	Corn Fiber Gel	Corn Bran
2.5	25	9,400	4	25	4
5.0	25	11,000	17	27	4
10.0	25	12,600	14	26	5
2.5	50	9,500	10	26	4
5.0	50	7,700	15	25	4
10.0	50	10,700	21	24	4

Table II. Influence of Co-Drying[a] Sheared Corn Fiber Gel with Hydrophilic Carbohydrate on Rehydrating[b] Properties for 3% Gels

Product	Viscosity, cP		Hydration Capacity, %	
	Drum Dried	Oven Dried	Drum Dried	Oven Dried
Corn fiber gel	6,200	7,300	23	19
Corn fiber gel & Oatrim-5	8,500	15,500	28	21
Corn fiber gel & guar gum	7,200	8,800	27	12

[a] Co-drying by either drum drying with 40 psi steam or by forced air oven at 65°C.
[b] Waring Blendor for 5 min.

Table III. Dietary Fiber Gels (3% Solids) Freeze-Thaw Stabilities

Composition	Viscosity, cP[a]				Viscosity Loss (%)
	Original	Cycle 1	Cycle 2	Cycle 3	
Corn fiber gel	18,000	12,400	15,000	9,400	48
Corn fiber gel	8,900	8,000	1,500	1,400	84
Wheat fiber gel	6,700	550	250	150	98
Oat fiber gel	1,275	130	160	124	90

[a] Freeze-thaw cycles 1, 2, and 3 are on the gels prepared from previously lyophilized samples in the frozen state for 24 hr before thawing.

products containing Z-Trim contained 1 g of fiber per 28 g. These spreads can indicate the added dietary fiber on the package.

In addition to using Z-Trim as a calorie reducer, it can be combined with Oatrim to give a snack item high oat β-glucan content. A 2-oz snack bar providing 2 g of soluble oat β-glucan was prepared by combining Oatrim-15 (13.3 g), Z-Trim oat fiber (1.0 g), aspartame (0.7), corn syrup (24.0 g), and milk chocolate (17.0 g). Cereals and fruit could be substitutes for the chocolate to provide different options for the snack bar. Other formulations could also be used to make a healthful snack food.

Conclusions

New fiber gels, called Z-Trim for their zero calorie value, are a new generation of fat replacer and texturizing ingredients made from a variety of low-cost fibrous products. Z-Trim gel particles absorb large amounts of water to produce huge deformable structures with high viscosities and smooth mouthfeel. By using Z-Trim, food textures can be adjusted to suit the product. Their different particle sources and sizes can give textural variation from creaminess to meat-like structure. Textures are suitable for hamburger, deli meats, cheeses, and some baked foods. Large reductions in calories are possible along with adding healthful amounts of fiber to the diet.

Acknowledgments

Special thanks to the following who allowed the development of Z-Trim. Steve Grisamore of the Mountain Lake Specialty Ingredient Company was the Cooperative Research and Development Agreement (CRADA) contact, who provided samples and managed the operation of their pilot plant facilities at Mountain Lake, MN, during the preparations of Z-Trim corn fiber, oat fiber from hulls and oat fiber from previously purified starting materials. C. S. (Sam) Rao of ConAgra Grain Processing Companies provided advice and guidance during some of the critical stages of development. Mike Walter of ConAgra Specialty Grains Company made it possible for the successful collaboration and results from the CRADA. Don Glover of the chemistry department, Bradley University, recommended at least six students for training who participated on the project during critical development stages. Richard Greene of NCAUR provided the leadership of the CRADA for the USDA, ARS, NCAUR research project in the Biopolymer Research Unit. Deborah Bitner of the Biopolymer Research Unit provided necessary services to make arrangements for the successful completion of the Z-Trim project.

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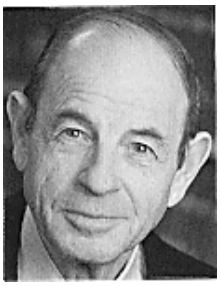

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