Spun-Fiber Textured Products

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ABSTRACT

The process for spinning fibers from soy isolate is described. Fabrication of so called food analogues and extenders containing spun soy fibers is reviewed. The rationale for the use of fibers in food products and ingredients is explored. Nutritional properties, especially protein quality, of the products are discussed. Emphasis is given to the fact that spun-fiber textured products contain a variety of items, such as soy, wheat, oats, egg albumen, yeast, sodium caseinate, and vegetable oils. The relationship of this variety to applied nutrition is discussed.

INTRODUCTION

In this session, we have heard Frank Horan describe the processes of preparing soy isolates and spun soy fibers, and Karl Mattil has described the nutritional and functional properties and quality criteria of soy isolate which is the starting material for producing spun fibers. We will review briefly the Miles procedure for manufacturing soy fibers, and we will describe the fabrication of so called analogues and extenders which contain these fibers. The term analogue in this paper connotes products which resemble conventional meat, poultry, and fish products in flavor, color, texture, and appearance. Extenders refer to those items which are designed to be used in combination with traditional products. In describing the procedure for preparing analogues and extenders containing soy fibers, we will point out that these products usually contain other sources of protein, such as wheat, egg albumen, gluten and yeast, and even other forms of soy protein, such as soy flour and concentrate. The nutritional properties, especially protein quality, will be presented. We will close with a brief discussion of the relationship of new foods to variety in foods.

SPUN-FIBER PRODUCTION

Figure 1 is a flow chart of the Miles process for spinning soy isolate into fibers, or more precisely, precipitating soy protein at its isoelectric point (pH 4.6) in the form of continuous monofilaments. The process is a modified version of the initial technique described by Boyer in his landmark 1954 patent (1). The isolate intended for spinning into fibers must meet certain specifications. For example, it should be free of crude fiber and extraneous matter and must have been dried in such a manner that rehydration and solution will be uniform.

In the process itself, the initial step is to suspend the isolate in water to a solids content of ca. 20% followed by raising of the pH to effect functional changes in the protein. An extremely viscous mass is obtained which is next filtered and pumped through a spinnerette immersed in a coagulating or precipitating bath (pH 2.5) of phosphoric acid and 8% sodium chloride. The spinnerette is a thin metal membrane or disc made of noble metals

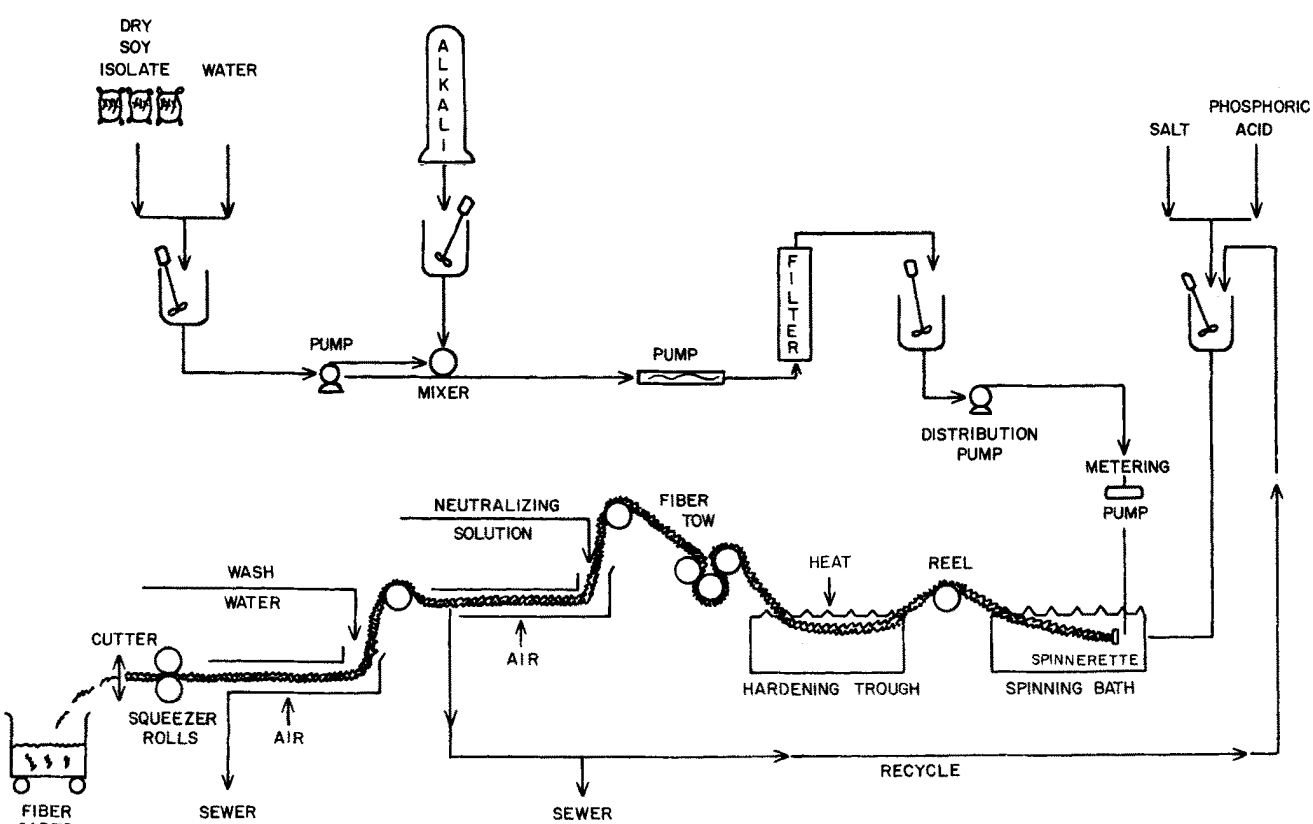

FIG. 1. Soy fiber spinning.

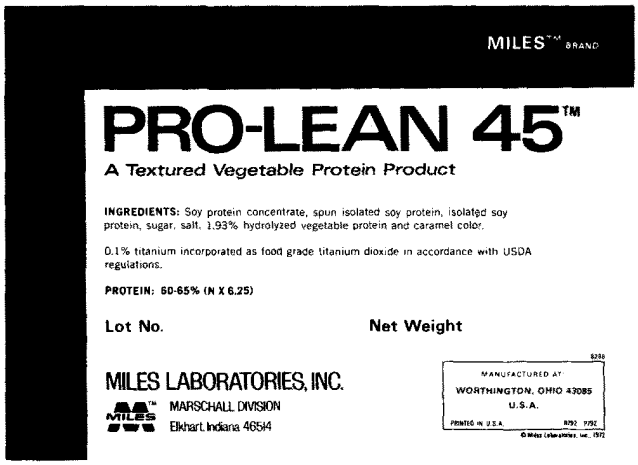

FIG. 2. Ingredients for textured vegetable protein product.

FIG. 3. Ingredients for non-meat product.

containing a large number of holes. At Miles, we use spinnerettes containing 15,000 holes, .004 in. diameter. Though it is protein monofilaments which emerge from the spinnerettes, the large number of monofilaments are handled in groups of filaments called "tows." The tows are drawn away by the take-away reel which travels at a speed somewhat greater than the extrusion rate of the fiber through the spinnerettes. The fibers are next heat-treated and then neutralized to a pH of 5.0-6.0. They are washed with tap water, excess water is squeezed out, and they are cut to a length smaller than 6 in. Depending upon the product in which the fibers ultimately will be incorporated, they may be later chopped or ground. They are then ready for use in the preparation of analogues and extenders.

It is important to note that fiber spinning is not a straightforward process. There are many variations used in spinning which are dependent upon the properties of the

TABLE I

Extended Ground Beef: Relative Costs

Item	30% Extension		45% Extension
	Extruded extender	Extruded extender with fiber	Extruded extender with fiber
Ground beef	$45.50	$45.50	$35.75
Hydrated extender	2.70	5.49	8.24
Total cost/100 lb	$48.20	$50.99	$43.99
Assumed costs			
Ground beef		$.65/lb	
Extruded extender		$.27/lb dry, $.09/lb hydrated	
Extruded extender & fiber		$.55/lb dry, $.18.3/lb hydrated	

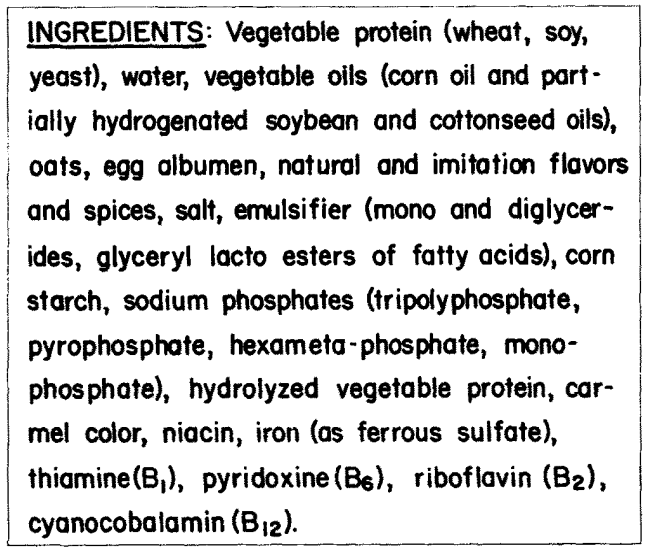

FIG. 4. Ingredients in breakfast links.

fibers we desire. These properties are defined by the organoleptic characteristics of the end products. An example of a step which can be varied is the take-away step. It has been found that the greater the speed of the take-away reel, the greater the stretching of the fibers with resultant increases in strength and elasticity and some reduction in fiber diameter. An excellent discussion of the science and art of fiber spinning can be found in the recent review by Gutcho (2).

TEXTURED PRODUCT PRODUCTION

Why go through the process thus far described for preparing soy fibers? Textured soy products may be prepared by extrusion processing. In our judgment, the major reason it is necessary to incorporate spun fibers into analogues and extenders to be used in combination with meat, at levels such as 45%, is to reproduce the texture of meat, fish, and poultry which derives mainly from muscle fiber. Thus, fabricated protein products containing fiber are unique, because, of all textured products, they most closely simulate the structural characteristics of animal protein. We would agree that fibers are not needed in products which are not analogues or are not going to be used as meat extenders at levels in the 45% range. There is a secondary nutritional benefit associated with the use of products containing spun soy fibers which we will discuss subsequently.

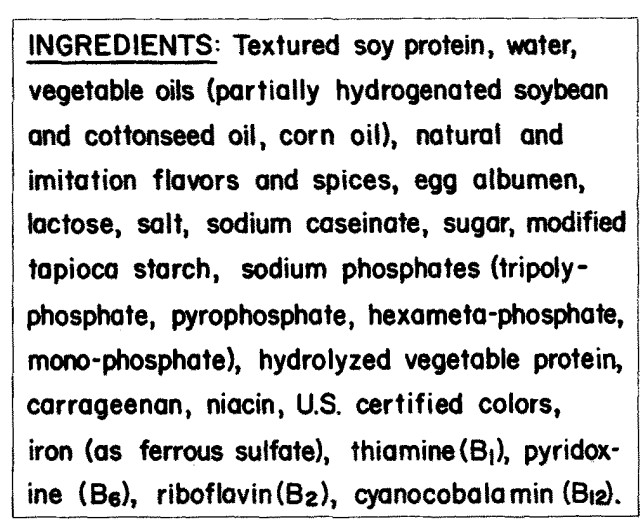

FIG. 5. Ingredients in breakfast slices.

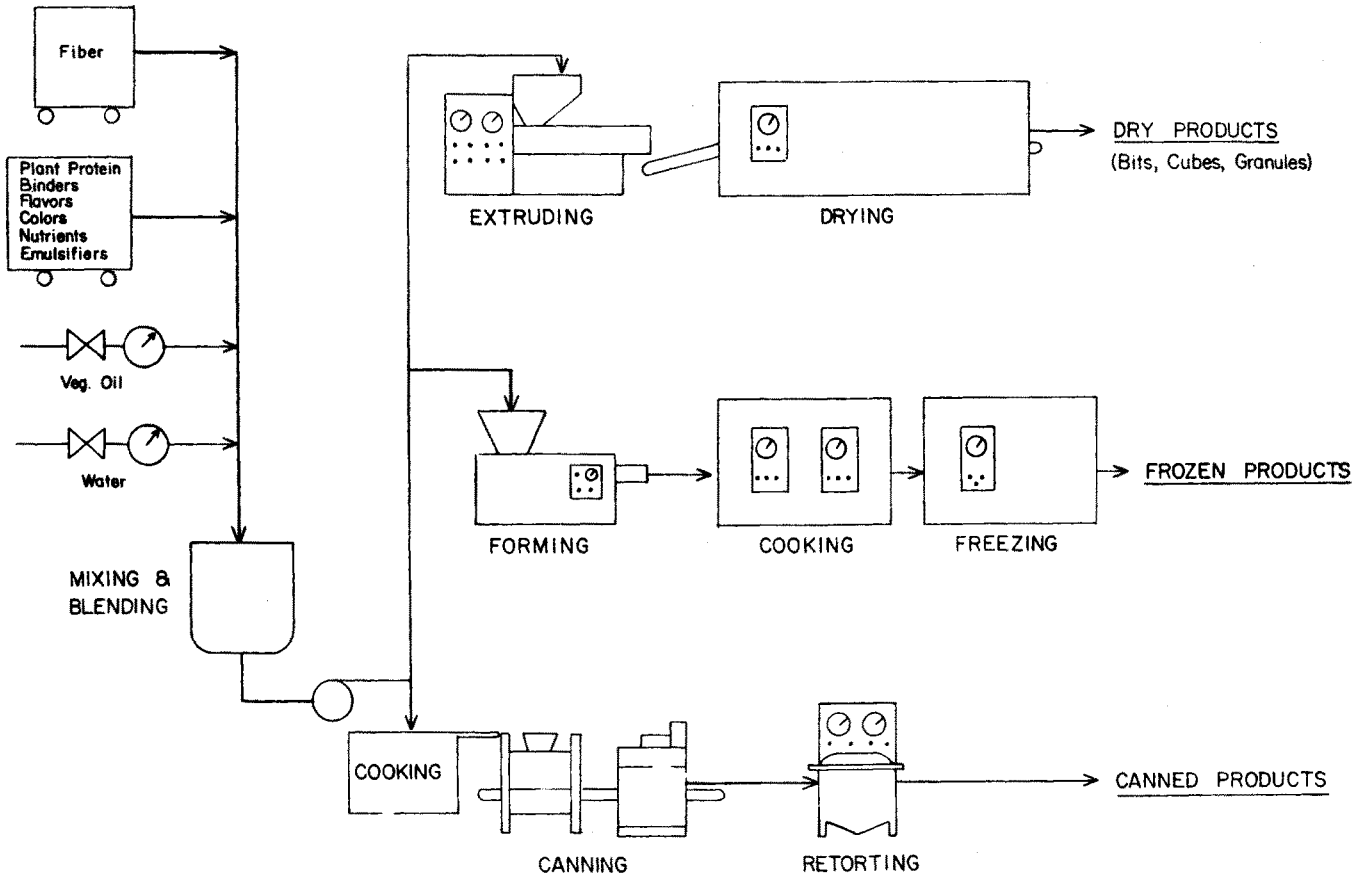

FIG. 6. Protein food processing.

There is a point regarding spun-fiber textured analogues and extenders which we would like to clarify. We believe that many consider such products to contain practically 100% fibers together with small amounts of colors, flavors, seasonings, and fats. In point of fact, these products contain anywhere from 20-50% fibers. The operating principle is simply to add only that amount which is needed for optimal texture in the end product. There are many types and combinations of ingredients which are used in so called spun-fiber products. The labels shown in Figures 2-5 clearly illustrate the wide variation in ingredients.

Fiber, which itself can vary depending upon the processing conditions, is only one ingredient, though the most critical ingredient from a texture standpoint. It must be emphasized that texture also is affected by the other ingredients and the processing techniques for preparing finished products from the ingredients. Preparation of spun-fiber textured products can be considered a model of the blending of the disciplines of chemistry, physics, nutrition, and microbiology together with "Edisonian" science into the field known as food science and technology.

In the process of preparing spun-fiber protein foods, we refer to plant protein ingredients other than soy fiber, binders, such as egg albumen, flavors, colors, nutrients, and emulsifiers and ca. equal wt water as serum. Serum formulation will, of course, vary depending upon the end product. Serum ingredients are mixed and blended with fibers and vegetable oil in ca. ratio of two parts serum, one part fiber, and one-half part vegetable oil by wt.

Figure 6 depicts the preparation of spun-fiber textured foods. It shows that blended serum, oil, and fiber go to one of three product category lines. These are the dry, frozen, and canned product lines. The dry product line illustrates extender production; the frozen and canned illustrate analogue production. It can be seen that we produce extruded extenders containing fibers. We think it is important to differentiate between extruded soy proteins containing fibers and those which do not. The functional properties, especially those relating to texture and flavor, are quite different. We produce both types and recommend that extruded fiber-containing products be used for meat extension levels 30% and higher to obtain desirable textures and flavors in the cooked combination product. While extruded extenders containing soy fiber cost more than extenders without fiber, Table I shows that there are greater savings at extension at the higher levels.

We want to emphasize that production of analogues and extenders containing spun fibers is a sophisticated process. One can readily appreciate the effect on end product characteristics due to the interrelationships among ingredients and processing of fibers, which are ingredients, and extenders and analogue foods. To have a food contain a desirable texture (either in a form of muscle fiber bundles, which simulate an animal product, or in a form which does not resemble a traditional product), it is important that some soy fibers be in the product. In a simplistic sense we equate fiber with sophisticated texture in analogues and high-level use extenders.

NUTRITIONAL CONSIDERATIONS

We have pointed out that spun-fiber textured products contain ingredients other than spun fiber. Thus, while we are interested in the nutritional value of the fiber itself, more consideration is given to the nutritional properties of the end product. For example, the ingredient statement we showed for the breakfast links (Fig. 4) listed wheat, soy, and yeast vegetable protein together with oats and egg albumen. The salisbury steak style entree (Fig. 3) showed similar ingredients but at different quantities. Since there are supplementary biological effects of proteins from different sources when consumed together, the protein value of these products is significant as measured by the protein efficiency ratio (PER). Thus, the PER of the

TABLE II

Quantity-Quality Protein Considerations[a]

Item	G protein in 100 g serving	PER	U.S. RDA protein in g	Percent U.S. RDA
Animal protein product	18	2.5	45	40
Analogue with spun fiber	18	2.2	65	29
Analogue with spun fiber at a higher protein level	26	2.2	65	40

[a]PER = protein efficiency ratio, RDA = recommended daily allowance.

breakfast link is significantly above 2.5. This assay is the most widely used tool to assess the nutritional value of proteins. Basically, PER is determined by dividing the wt gained by test rats after 4 weeks of feeding on a diet containing test protein by the wt gained by rats fed a diet containing casein, the principal protein of milk. Casein's PER usually is considered to be 2.5, and the test protein's PER is adjusted correspondingly.

Spun-soy fiber textured products, as noted above for the breakfast link, can, and indeed do, have PER values equivalent to or higher than that of milk protein, namely 2.5. Nevertheless, some of the products containing spun fiber now have values less than 2.5, i.e. 2.1-2.4. Miles currently is investigating reformulation possibilities of protein sources to raise the PER of these items to 2.5. We also are studying levels of methionine which might be used alone or in combination with reformulation to increase the PER. In this forum, it is appropriate to note there are taste and odor problems associated with the use of methionine which may not be solved completely. We are looking into the possibilities of using methionine polymers or binding the amino acid to a protein ingredient in the food to prevent development of objectionable flavors.

Table II illustrates the point that protein values of analogues with PER's between 2.0-2.5 can be made nutritionally equivalent in protein value to that of meat products without raising PER but increasing protein quantity instead. This is possible in view of the nutritional interrelationships of protein quantity and quality. Consider a product with a PER of 2.2 and protein content of 18%. If the recommended daily allowance (RDA) for protein with PER's less than 2.5 is 65 g, then a 100 g serving of this analogue would supply 29% RDA. If a traditional meat product has a PER of 2.5 and also 18 g protein, it would supply 40% of the RDA, according to the U.S. Food and Drug Administration, which specifies that the U.S. RDA for protein of PER 2.5 and higher is 45 g. An increase in the protein content of the analogue from 18-26% now would supply 40% U.S. RDA for protein. Thus, the food processor has the option of increasing protein quality as measured by PER assay or increasing the protein content.

There are other possibilities being discussed in the U.S. concerning nutritional equivalency of analogues and animal products. One is defining a protein food in terms of percentage of RDA supplied by 100 g product. Parenthetically, we might add that a number of processed meats, especially those high in fat, do not have a PER of 2.5.

It is possible to fortify analogues and extenders with vitamins and minerals to meet nutritional requirements. Currently, extenders for use in the school lunch program of the U.S. Department of Agriculture must contain specified levels of magnesium, iron, thiamine, riboflavin, niacin, pantothenic acid, and vitamins B_6 and B_{12}. There are, as one would expect, quantities of these and other vitamins and minerals naturally present in the spun-fiber textured products, since a variety of ingredients are used. It is our understanding that U.S. governmental agencies will soon be proposing nutritional guidelines which will specify types and levels of micronutrients which must be present in analogues and extenders.

We will only note that spun-fiber protein products may contain no cholesterol and animal fat. The polyunsaturated to saturated fat ratios are usually in the range of 1, whereas in meat the ratio is ca. 0.3. Also, calorie content may be less than that of traditional products, often by as much as 50%. Consequently, protein to calories content in these products is higher. These are plus factors for those people who wish to modify their diets as part of a total approach (i.e. physical exercise, smoking elimination) to preventing coronary heart disease.

CONCLUDING REMARKS

It is appropriate to conclude this paper with a brief mention of the concept of variety as related to food consumption. Most would agree that there is less variety in man's diet in developed countries than before. Some attribute this to the increasing use of processed foods. In less developed countries, there is limited variety in diets due to economic constraints. Where options for consuming variety are limited, then teaching the consumption of a variety of foods is of limited value. Yet food variety is a sound concept, since each individual can increase his chances of consuming known nutrients, as well as any of which we have no knowledge. Surely, this is a reasonable approach to applied nutrition. It does not say there are unknown nutrients, but it does say that, if there are any, then consuming a variety of foods minimizes the chances of not consuming them. We suggest that consumption of analogues which contain diverse ingredients, such as soy, wheat, oats, eggs, yeast, milk protein, and vegetable oils represents an opportunity for increasing variety. Actually, the entire food industry might give deliberate attention to broadening the base of ingredients which go into fabricated foods to create variety of ingredients in single foods. The use of a variety of food ingredients and nutrients, together with advances in food processing and nutrition knowledge, now makes possible the fabrication of new foods which have the desirable aesthetic and nutritional properties of traditional animal foods.

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