THE CHALLENGE FROM MEAT SUBSTITUTES TO MEAT AND NUTRITION

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Although there are several very good reasons why we eat meat, from the standpoint of nutrition perhaps the most important is its high content of good quality protein. There are other nutrients that are contributed by meat such as fat, iron and certain vitamins, but by and large we think of meat as synonymous with protein. A significant part of the world's population does not eat meat for religious reasons and these people presumably can maintain themselves in good nutritional condition by consuming their protein in the form of vegetables and nuts and satisfying their iron and vitamin needs from non-meat sources. For many years there was a widely held nutritional concept that animal protein differed in some mysterious way from vegetable protein but this idea has long since been proven to be fallacious. It is now established that the nutritive quality of protein is dependent upon its amino acid composition, although other factors may affect certain nutritional characteristics. In general, the amino acid composition of meat favors a higher nutritive value than most vegetable proteins, but certain protein-rich legumes such as soybeans, and also certain mixtures of vegetable protein sources may equal the nutritive value of meat protein. On the basis of nutrient composition there is, of course, no reason why a vegetarian diet might not be just as nutritious as a meat-containing diet.

Much has been said and written in recent years that places a mark of suspicion against certain meats and other animal products in the ischemic heart disease controversy. This is not the place to air the pros and cons of this argument. Suffice it to say that the leanest cut of meat still contains 50 percent of its calories in the form of fat and that cholesterol is a substance that is found only in the animal kingdom and therefore becomes a part of our diet by way of certain animal products. Furthermore, saturated animal fats and dietary cholesterol are two among many factors that are believed to be contributory to ischemic heart disease. I do not wish to place undue emphasis upon this aspect of the nutritional properties of meat products versus vegetable proteins. Nevertheless, even though my personal prejudice opposes any incrimination of meat on these grounds, I must admit that the argument does favor vegetable protein and I will discuss this problem in somewhat more detail later in this presentation.

To sum up what has been said, vegetable protein can provide nutritional benefits equivalent to those of meat protein. Furthermore, if one attempted to balance all nutritional attributes that have been discussed, both favorable and unfavorable, the final score would probably give an edge to vegetable protein. Fortunately for the meat producers, this does not tell the whole story. There are two very important nutritional reasons why

there is no immediate possibility of vegetable protein, to any large extent, replacing products of animal agriculture. These are, first, the fact that relatively few vegetable sources are sufficiently rich in high quality protein, and second, the fact that the nutritional properties of a food have meaning only when that food is ingested and, with the exception of a few areas in the world, vegetable sources that are rich in high quality protein are unknown as human food and without extensive promotional efforts will not be consumed in significant quantities.

Let us examine these two problems in more detail. Of the vegetable sources of protein that satisfy to a significant degree both criteria of high concentration and high quality protein, the oilseeds such as sesame, peanut, cotton, and soybean have received the most attention. Many other plant protein sources are being studied intensively and these include yeast, algae, plant leaves, and most recently, high lysine corn. Perhaps each of these has some potential but only a few, such as soybeans, peanuts and cottonseed, have been examined extensively in human feeding studies and show promise of immediate applicability. Cottonseed, after the oil is removed, is used primarily as cattle feed. A component of the seed called gossypol is very toxic to non-ruminant animals, including man, and must be removed. Unfortunately, the process of removing gossypol is somewhat costly and without special precautions this purification results in a serious loss of nutritive value of the protein. Nevertheless, cottonseed flour is being test-marketed in certain economically depressed countries, although for the most part, not in forms that substitute for animal products. Peanut oil cake is being used in certain depressed countries as a source of protein for human consumption. Such utilization has been seriously hampered by the contaminating of the press cake with a fungal toxin. Some headway has been made in isolating peanut protein, a step that will have to be accomplished if simulated meat products are to be made. However, present use as a food protein is in a non-meat form and largely directed to a vegetarian population.

It will simplify my task considerably if I can restrict discussion to one protein source which has probably been most extensively and most successfully studied of all. I refer to soybeans and derived protein products from soybeans, including soybean flour, soybean protein concentrate and isolated soybean protein. This oil seed fulfills the requirements for amount and quality of protein. Soybean meal from which the oil has been extracted contains roughly 50 per cent protein. This protein is well digested by man and animals and is as well utilized as most animal products. In other words, its nutritional quality is very high.

In spite of these beneficial attributes there are certain apparent restrictions in its acceptability as human food. Soybeans have been known for generations and in parts of China and Southeast Asia they are a major component of the diet. However, in those countries where soybeans are important as human food, the soybeans have been altered by chemical or fermentative changes before their consumption. The changes involved in making soybean curd or mold-fermented tempeh that have resulted in acceptability as a food may be entirely related to flavor and texture. However, soybeans, like most legumes, cause extensive flatulence and the production of bulky, foul-smelling feces. Recent studies support the view that these undesirable characteristics are caused by the presence of certain soluble carbohydrates. The native processing that has been referred to probably removes most, if not all of these carbohydrates.

In this country, many attempts have been made to introduce soybean products as major food items. To my knowledge, no product which contains a high proportion of essentially unaltered soybean has satisfactorily met the test of acceptability. Thousands of carloads of soybean flour are incorporated into foods each year, but essentially all of this material ends up at very low concentration in breads, doughnuts, other pastries, breakfast cereals and the like. Such food uses of soybeans cannot be thought of as substitutes for meat, although to an important degree a substitution for milk has been affected.

The commonly recognized excellent nutritional properties of soybeans have led to widely proclaimed expectations that they will relieve the shortage of animal protein in the underdeveloped countries of the world. This philosophy existed after World War II, when thousands of tons of soybean flour were shipped to Italy for protein fortification of macaroni and spaghetti. It rotted in the warehouses because no one knew how to use it. This was also true during the past few years when soybean flour and special food formulations containing soybean flour were shipped to underdeveloped countries where soybeans were unknown and the products again rotted in the warehouses even though the people were starving for protein. There are ways in which a small amount of soy flour can be disguised in a food formulation such as bread or pasta, but I believe that no pressure can be great enough to make a non-soybean consuming population eat significant quantities of whole soybeans or soybean flour without disguising their presence. The quantities I am talking about are the quantities that one might interpret as substitutions for meat. This same principle undoubtedly applies to any of the other oil seed protein sources, although unpleasant gastrointestinal effects of soybeans may have special significance.

All of this might lead to the conclusion that I am opposing the concept that soybeans and other vegetable sources of protein can effectively substitute for meat. This is far from my intent, but I do believe that unless new technology is employed, major introductions of soybeans into the diet of man will probably fail except in those populations where generations of use have led to effective, even though not new, techniques for altering soybeans through chemical or fermentation procedures. Modern soybean technology is showing promise of overcoming problems associated with the introduction of significant quantities into the diet of man. This technology undoubtedly will also be applied to other potential sources of food protein. The food industry now has available soybean protein concentrates in which the soluble carbohydrates have been removed; isolated soybean protein which has functional characteristics that make it a particularly valuable adjunct in meat products such as sausage formulations; and finally, fibrous soybean protein which makes possible the creation of texture characteristics that simulate meat to a remarkable degree. Presently available technology makes it possible to convert soybean protein into products that have the appearance, texture and flavor of meat. Four types of difficulties have retarded this development. First, the process is too costly; second, without expensive protein supplementation nutritional quality will not be good; third, taste qualities must be improved before completely satisfactory simulation can be realized; and four, a market has to be developed for the different types of products that can be manufactured. At least one simulated meat product appears to be gaining market acceptance, but this is essentially a flavoring product resembling crisp bacon bits and certain of the problems

relating to the type of protein substitution that I have been discussing are not involved. In order to understand better the problems involved in making simulated meats we can examine the manufacturing steps involved and some nutritional properties of the products.

By proper extraction procedures, the majority of the protein can be separated from the fiber, hemicellulose, soluble carbohydrates and other non-protein components of the soybean. The protein is most soluble in alkaline solution and, therefore, this is the usual condition for its extraction. Nutritionally the limiting amino acid in soybean protein is methionine and unfortunately this amino acid is quite labile in alkaline solution, and as a consequence, some nutritional value is lost in the initial extraction. It has also been found that a small fraction of high nutritive value protein is not extracted by this procedure. The extracted protein is precipitated in acid solution and washed so as to remove impurities and then dried.

A slurry is made of the isolated protein and it is dissolved by mixing with alkali. This solution is then forced through a spinneret into an acid solution which immediately precipitates the protein fibers. More methionine is probably lost at this stage since a strong odor of hydrogen sulfide is reported to prevail. I have not been able to obtain any protein fiber at this manufacturing stage for nutritional assay, but I assume that nutritional quality has been decreased. This shows the appearance of the protein fiber in the precipitating bath and this gives a magnified view of the dried fibers. These fibers are pressed together in the presence of suitable binders, coloring and flavoring agents to give simulated meat products that may take many forms. For example, in the next slide is shown a commercially prepared simulated chicken product. Notice the composition which lists besides fibrous soy protein, corn oil, albumin, soybean protein, vegetable gum. In addition to the relatively high cost of the soy protein fibers, the egg albumin must contribute considerably to the total cost of the product. It is my guess that a fairly large quantity of egg albumin is required to provide the necessary texture quality and this albumin also contributes a great deal to the final nutritional value of the protein, as we shall see later. This product was obtained in fairly large quantity so that they could be freeze dried and the fat extracted for the measurement of protein nutritive value in rats. There are dozens of other simulated meat products that are marketed in specialty food stores. Most of the other products are made from wheat gluten rather than soybean protein and I have not examined them for nutritive quality. I was intrigued by the apparent paradox involved in these products for they are intended for consumption by vegetarians, who for religious reasons cannot eat meat, yet they are sold to the consumer as products that look and taste like meat, but without mention of their similarity to meat in nutritive value. In order to evaluate protein quality we used the simple protein efficiency ratio measurement which is carried out in young, growing rats. The protein is incorporated into a diet of completely defined composition that is made up of purified ingredients and the protein level is adjusted to exactly 10 per cent of the diet. First, let us look at the composition of the two simulated meats as compared with an all-meat frankfurter, some very good grade ground beef and a good quality cured ham.

The fat and protein analyses are interesting. If we assume that high fat meat products are nutritionally undesirable and that the desirable characteristic is high protein, it is evident that the three meat products score lower than the simulated meat products. The frankfurters represent the most expensive, all-meat product available in local retail stores. This is a national product recognized in the industry for the excellence of its composition and quality control. A quick calculation shows that roughly two-thirds of the calories provided by this product are in the form of fat. A calculated ratio of fat to protein content given in the last column provides a type of nutritional index; the lower the ratio the more nutritionally desirable the product. This gives the most dramatic illustration of how the tailor-made products have been put together with some awareness of nutritional characteristics which would lend themselves to the formulation of low fat diets. These figures again single out frankfurters for their very poor balance between fat and protein content.

With these data, diets were compounded which contained 10 per cent protein and 15 per cent fat plus all known essential nutrients. A diet containing casein as a standard protein was also included and groups of male, weanling rats were fed the diets for 4 weeks.

Two of the meat products, ground beef and ham, were not included in this experiment. The soyameat simulated chicken appeared to give a slightly slower growth rate than the standard casein. A peculiar drop-off in growth rate after the second week was observed with the frankfurters. This was somewhat alarming because it could have been a reflection of toxic levels of curing agents or some other component of the product. Frankfurters were included in a second run and no latent decrease in growth was obtained, so this peculiarity has been chalked up to "biological variation" for lack of any adequate explanation.

Nutritional quality of protein is usually expressed as an index of its utilization by the animal. One of the most simple and yet most reliable indexes is the protein efficiency ratio. This is a numerical expression of the gain in weight resulting from the ingestion of a given amount of the protein. The calculation is grams gain in body weight divided by the grams of protein eaten. By convention, this ratio is normally determined when 10 per cent protein has been included in the test diets. Two experiments of this type were run and the protein efficiency ratios or PER's are given. The two experiments show reasonably good agreement for the duplicate runs of casein and frankfurters. Casein, ground beef and ham are essentially equal and very slightly superior to the two simulated meat products and frankfurters. The conclusion that I draw from these data, and I must confess a surprising result to me, is that the simulated products contain protein that is essentially equal in nutritive value to meat. Isolated soybean preparations that I have assayed have always given considerably lower PER's than casein. I have never tested the fibrous soy protein by itself. However, egg albumin is particularly rich in methionine and relatively small amounts added to isolated soy protein very effectively increase the nutritive value of the soy protein.

For example, in one such study run in our laboratories an isolated soy protein had a PER of 1.9. Five per cent of the soy protein was replaced by egg albumin. In other words, the test diet contained 9.5 per cent soy

protein and 0.5 per cent egg albumin protein. The PER of the mixture protein was 2.5. On the basis of this magnitude of supplementary effect of egg albumin, I would assume that approximately 5 per cent egg albumin protein incorporated with the fibrous soy protein would give the high PER's that are shown.

There are, of course, extensive possibilities for simulating meat products. I have tasted simulated ham, turkey, smoked turkey, a variety of specialty sausages. Simulated bacon bits, as you probably know, are commercially manufactured and marketed. This represents a line of special flavor and cocktail snack products simulating cooked shell fish and a variety of deep fat fried tidbits that are currently being developed. These products do not carry the connotation of being significant protein sources in the diet, and therefore nutritionally should not be compared with the meat substitutes that I have been discussing.

I would like to return to the question of getting people to eat significant quantities of vegetable protein. As I have said earlier, soybeans and probably other vegetable proteins will not be consumed as major sources of protein in the diet unless they are changed in some manner from their natural state. In less developed countries possessing soybeans over the past centuries, highly acceptable food products have been developed. These products, such as tofu and tempeh, have not simulated and thus have not replaced other established food products. On the other hand, soymilk, which is still used very extensively in Asian countries, does simulate to a minimal degree, human or cow's milk. The movement to develop vegetable protein products which is underway in this country has gone in the direction of a meticulous imitation of meat products and it would be my guess if this extends to simulated milk, the product will very accurately duplicate the flavor, texture and appearance of cow's milk.

I am sure there is some way to go before these products can substitute for meat or milk, since they still fall short in taste quality and they are still expensive. Nevertheless, technological potential of this country's industry will readily overcome these problems, if there is an established market potential. The factors that govern such a development are too far beyond my scope of knowledge to discuss. I have tried to give a picture of the commonly thought of nutritional implications which center about the amount and quality of protein. I would like to close with a few comments regarding the nutritional implications related to the controversial subject of dietary fat and ischemic heart disease.

There are many faddish ideas of dietary control over heart disease. I say faddish, for fad means a whim or fancy of a temporary nature and held without reason. The temporary nature of the dietary side of this question is clearly illustrated by the changing attitudes of a few scientists who have moved from low fat diets to high fat diets with major replacement of unsaturated for saturated fat, to low calorie intake without regard to kind and amount of fat, to extremes of low fat diets. Along the way we have also been told that we should eat a low protein diet, then later a high protein diet has been recommended. More recently, favoritism was given to a low carbohydrate diet; then ideas changed and a high carbohydrate diet with restriction of simple sugars was advocated. One of the most recent proposals in this stream of changing attitudes is that we should eat a low fat-high

carbohydrate diet, but with carbohydrates that do not contain appreciable quantities of simple sugars such as glucose and sucrose. This, the advocators of the diet tell us, will provide the American with a diet similar to the Asian who, it is reported, has a very low incidence of ischemic heart disease. If this type of diet is to provide adequate protein and yet have a very low fat content, it cannot contain major quantities of meat, because of the high fat content of meat. This type of diet formulation has been accomplished by investigators at the University of Iowa by using soy protein simulated meat products and natural grains for carbohydrates. The diet, containing only 15 per cent fat, no cholesterol, and only complex carbohydrates, was fed to prisoner volunteers and a few students, and at the Federation meetings in Atlantic City last April it was reported that the diet was easy to take and that blood levels of cholesterol were reduced significantly. What effect this type of extremism will have on the development of a market for simulated meat products is anyone's guess. I believe the major point to consider at this time is that meat substitutes, containing good quality protein and at the same time very low fat content, are feasible to produce. Reasons, such as, that availability and price of meat are unfavorable, or that unique nutritional benefits may be derived from the substitute products, will dictate their use. In general, I would assume that the factors governing the potential marketing of meat substitutes will be primarily economic, not nutritional. A similarity in the soybean product substitution for milk might be cited as an example of how economic factors can bring about changes in food consumption patterns. Current shortages of milk have led to increased substitution of soybean products in food items such as bread. Governmental decisions that milk production will not be increased so as to supply the underdeveloped countries have given a tremendous impetus to develop vegetable protein substitutes for milk. Product development for foreign markets may also have an effect upon domestic uses, as, for example, a highly sophisticated milk substitute for infant and child feeding. The primary goal may be the feeding of starving children, but the end result may include the feeding of healthy, U. S. babies. Whatever conclusion you may wish to draw today, you cannot avoid the fact that meat substitutes are offering a challenge to meat and to nutrition.

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THOMAS BLUMER: Thank you very much Dean Barnes and I am sure that this group will accept the challenge from meat substitutes. So for the discussion then of these two very excellent papers I will call on our good friend Bill Sherman.

BILL SHERMAN: Thank you, Tom. I think now that you can see one of the many reasons why I personally was happy that we were going to hold this conference at Cornell. At Cornell there is such an excellent staff of extra special nutritionists that we could call on, that it made our nutrition part of this program a very easy one to plan. Dean Barnes' group is so widely diversified that you can pick an expert in any field that you want. I was glad that Dr. Young gave us the background information that she did. This obesity problem is a very complex one. We