FUTURE FOODS - A LOOK AT SINGLE CELL PROTEINS

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The world is full of people and every year there are about 70 million more. Because of a marked decrease in the death rate, our population is increasing at an unprecedented rate and will continue to do so either until disaster strikes or until we are ready to colonize other planets in the very distant future.

In spite of our increasing population, the day when we will run out of living space is not yet at hand and is something for future generations to cope with. Without a doubt, the greatest challenge facing the world today is the race between the increase in population and food supply. Can we win this race? Malthus did not think so, but, with due respect to Malthus, I feel rather confident we can, thanks to advances in research, agricultural technology and, wishfully, population control. The problem we face is that people live longer, bear more children, and that the children have a better chance of survival. The figures are truly staggering. Every half a second, a child is born. In the year 1966 alone, the population of the world increased by 70 million people and it is estimated that by the year 2000, 6 billion people will be crowded onto the surface of the earth. This is twice what it is now and the frightening aspect is that most of the increase in population will be in developing countries where food is in short supply even now.

Overcoming the problem of world food shortage has many aspects. Providing sufficient protein is probably most important because it affects primarily children and their chance for survival and for growth and development. To visualize the magnitude of the problem, we must recognize that the production of high quality protein to feed the estimated 6 billion people in the year 2000 A.D. must be tripled.

The importance of protein in the diet really cannot be overemphasized. It provides the nitrogen and the amino acids for the synthesis of body proteins and other nitrogen containing compounds such as creatinine, histamine, epinephrine, thyroxine, the heme-prosthetic group of oxidative enzymes and hemoglobin. Indeed, protein in excess serves as a source of energy which is the reason why one cannot eat all the protein one wants to and still lose weight. It is in a sense unfortunate that, if the simple caloric requirements of the body are not met by the consumption of carbohydrates and fats, amino acids will be used as sources of energy and hence will not be available for the synthesis of body proteins.

So far, I have stressed the importance of protein in our diet and pointed up that there will be an ever growing protein gap as our population increases unless we find ways to substantially increase protein production each year. Let us first take a look to determine how this could be accomplished depending on present sources of protein.

It may seem strange to us but 70% of the world's protein supply comes from vegetable sources and only 30% from animals. Since the world population increases presently at the rate of about 70 million people per year, as I have stated before, and since it has been found that each person needs to consume approximately 52 pounds of protein per year to be adequately nourished, we are faced with the staggering problem of producing about 3.6 billion pounds of additional protein each year. Let me repeat, to feed the world population adequately, we need, each year, 3.6 billion pounds more protein than in the previous year. If we relate this to the United States where the protein of choice is animal protein, it would mean that, if eating habits remain unchanged, we must increase meat production by the equivalent of an additional million beef cattle per year. Since we know that animals are relatively inefficient sources of protein - the cow, for instance, eats approximately 6 pounds of vegetable protein for conversion to 1 pound of animal protein - the quantity of animal feed and grazing lands required is absolutely enormous. If you then ask why we don't use plant protein concentrates as human foods, we find that we run into other difficulties. In leafy vegetables, for instance, the protein is accompanied by approximately the same amount of fiber and the human digestive tract is not adapted to handling large amounts of fiber. Also, (agriculturally speaking) of the 30% of the world's surface that is solid ground, approximately 4 billion acres are potentially available for the growing of crops. Of this, roughly 80% is already under cultivation. If the remaining 20% of tillable soil were utilized to its maximum, it would at best supply enough food for the present population, but would be unable to feed the anticipated large increase in population growth. This is true even though agriculture is making great strides and the yield per acre of land has been improved almost beyond belief. For instance, a new variety of rice, IRI-8, has been developed recently in the Philippines which could be instrumental in doubling the world's rice production still in this decade. IRI-8 is a dwarf variety which outproduces the varieties of rice now grown in Asia by 65% to 300%. Similarly, scientists at Purdue have discovered a corn mutation which supplies most of the amino acids the body needs to make proteins, although normal corn lacks two of the essential acids, lysine and tryptophane. The Purdue geneticists discovered that the mutant gene Opaque-2 shuts down production of zein, a non-nutritious protein, thus leaving the building blocks free for the production of the lysine and tryptophane.

It now behooves us to look at new sources of edible proteins and when I stated before that I thought the challenge of feeding the increasing population could be met, I was thinking primarily in terms of such new sources as proteins from algae, from oil seed crops, from fish, and especially from single cell organisms. Since most of you are probably familiar with proteins from soya beans and since the availability of proteins from algae is still far in the future, I will restrict my remarks to fish and single cell organisms.

Water covers 70% of the earth's surface and teems with fish which represent an almost inexhaustible supply of protein if adequate conservation methods are utilized in harvesting the fish. I use the word harvesting deliberately because the way we fish today we take only about 15% of the fish from the waters of the world that could be taken. It is estimated that the seas could supply up to 500 billion pounds of fish annually although this figure is questionable in my mind and people like Ehrlich at Stanford definitely do not agree with it.

Of course, it would not be expected that fish protein will be consumed in its basic form or even as fish flour, but that fish protein concentrates will become a standard ingredient in cereals and other grain products up to concentrations of 10% which is the maximum that can be incorporated without affecting the flavor of the food items.

Perhaps the most interesting new protein available today is the single cell protein. To give you an idea why I think so, let me quote these figures: a cow weighing 1,000 pounds when fed by grazing can synthesize about 1 pound of protein per day whereas 1,000 lbs. of microorganisms growing on paraffinic hydrocarbons can synthesize about 2,500 lbs. of protein per day. We can hence estimate that approximately six billion pounds of protein, which is equivalent to the world's present protein deficit, could be produced by means of microorganisms at the expense of less than 1% of the world's annual production of 700 million tons of crude oil production. If we then recognize that today the annual world production figure for petroleum and natural gas actually approaches two billion metric tons, we can begin to see why the thought of using this type of protein to alleviate the hunger of the masses is a most exciting one.

At this time, I should probably explain what is meant by the term single cell protein. It is a word coined to avoid the typically negative attitude of laymen toward the concept of eating microbes which includes bacteria, yeasts, molds, and some algae. Of course, there is really nothing to worry about since most of us eat microbes almost every day in such foods, for example, as cheese or yogurt.

The production of single cell proteins is rather interesting. The heart of the process consists of a conventional fermentation using a variety of inexpensive carbon sources. For years yeast has been grown on molasses and the products used in foods and feeds and it may come as a surprise to some of you, but it was reported in 1906 that bacteria would grow on methane. Since that time, hundreds of microorganisms have been found capable of oxidizing one or more hydrocarbons. Most attention is being given today to yeasts grown on normal paraffins or natural gas and to some extent to bacteria grown on methane, normal paraffins, or a gas-oil fraction. Since I believe that single cell proteins will become a major protein source of the future, let me list some of the advantages of microbiological cultures over traditional agriculture.

Most microorganisms have a high protein content, usually 30-60% of dry-weight, and their culture offers a concentrated source of protein.

Because of the unicellular nature of the biomass, there is no differentiation of the cells into various tissues. The biomass can be processed as a whole and there is no need for a preliminary step such as picking fruit or digging roots, or cutting a carcass. However, we do find it necessary at times to extract the protein from the microorganisms to make it more easily available.

Microorganisms have a high density cropping and can be cultivated in compact units in contrast to traditional agricultural methods which require vast areas of land with relatively low yields.

The rate of growth of microorganisms is much greater than that of plants and animals. Microbes can synthesize proteins up to 10,000 times faster than cattle.

The cultivation of microorganisms is independent of climatic conditions and the seasons of the year. Their growth is predictable and can be maintained at optimum level by applying sophisticated control equipment and a controlled environment.

Microorganisms grow continuously 24 hours a day.

One microorganism or another is able to utilize most carbon sources and the variety of starting materials for protein production is almost without limit.

The chemical composition of microorganisms and hence their nutritional value can be controlled by controlling environmental conditions, genetic variations, and substrate media.

Microorganisms can be cultivated in every country and every part of the world from indigenous carbon sources. This means that it should be possible to bring better nutrition to the people independent of the trade balance, softness of the valuta and availability of foreign exchange.

In a few minutes, I have now covered what took many years to accomplish: products ready for the market place. However, there are still some problems to be explored before single cell proteins can become a commodity of convenience. Particularly some of the minor components, such as the nucleic acids which might have to be studied if we are to use them as a major factor in our diet. How then does our rapidly advancing technology affect the foods of the future?

As I have pointed out, we should expect to utilize new and different processes and raw materials and thus give rise to new and different foods. Yet, I would venture an educated guess that even by the year 2000 A.D., the eating habits of at least the people in the more prosperous parts of the world will not have changed radically.

Certainly, our foods will change. We will see many more manufactured foods on the market. Foods will be more convenient, they will be pre-cooked, take less time to prepare, be portion-controlled, and, hopefully, they will be stable at ambient temperatures. But they will look and taste pretty much the same as today even though they may be what we now call "ersatz." Of course, if enough of an ersatz material is used widely enough and long enough, it becomes the prime standard and is accepted as the real thing. I can say without hesitation that a strawberry ice cream made only with natural strawberries would be unacceptable to the average consumer today. There are good and valid reasons for this.

Food preferences and habits are not something we are born with. They are not inherited. Rather, they are psychological phenomena based on education, environment, and ethnic background. What this then means is that it takes at least a generation to materially change people's eating habits.

Now why is the psychology of eating so important? Why don't we make it easy on ourselves and pop a nutritious pill into our mouths whenever we feel hungry or the need to restoke our internal fires? Why don't we just chew on an unflavored capsule? If we did, we would be terribly frustrated and, by the way, constipated.

What does this mean with respect to single cell proteins? It means that they must have utility beyond their nutritional value. They must supply a functionality so that they can be used as building blocks for manufactured foods. Investigations, including work in our laboratories, have indicated that single cell proteins do have functionality and are amenable to treatments to give them even better functionality. They can be formulated into a great variety of food products, replacing other protein components, such as milk or cereal grain.

The fact that single cell proteins have functionality as well as nutrition is important because we all prefer foods with which we are familiar, whether they are natural or fabricated.

The psychology of food acceptance is what sells foods to us. This is what makes us try something new and this is why it is so difficult to improve the nutrition of the underfed people in developing countries. You and I will try a new food because we are educated people and because we are aware that the new experience might be pleasurable. The uneducated masses feel differently. They will not try anything new and people have been known to starve rather than consume a food with which they were not familiar. This then means that we literally have to sneak nutritive ingredients into their daily diet without their noticing it and this in turn means that, while we will have new foods in the more sophisticated parts of the world, foods for the others will not change, at least as far as sensory stimulation is concerned.

But what about us? By 2000 A.D., our offsprings will routinely include dishes in their menu which we would regard as exotic and adventurous An algae soufflé flavored with seed meal bacon chips, a single cell steak that comes from a petroleum refinery instead of the side of a steer, "butter" that contains fats which never existed in nature, lobster Newburg made with fish protein concentrates are not out of the realm of possibilities. Indeed, some of these foods are already available.

What I am saying and where single cell proteins fit in is that foods of the future will, to a great extent, no longer be pre-processed modifications of natural or grown foods, but actually manufactured foods designed to satisfy both the necessities and the aesthetic pleasure of eating. They will probably be of the intermediate moisture type so that they can be eaten out of hand as mini-meals or reconstituted into gourmet dinners. They will be nutritious, perfectly flavored, with controlled calorie content, portionized, and shelf-stable. Well, I cannot promise you that there will ever again be Manna from Heaven, but I can guarantee you that the custom of eating is here to stay.

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C. F. COOK: Thank you very much Dr. Konigsbacker. I think you will all agree it was a most interesting paper and I would ask him to keep his suit of armour on until the discussion period because I am sure many people will want to ask him some very interesting questions. Before we go on to the next speaker why don't we all get up for a few minutes and stretch because it's a very difficult period right after lunch and then we will continue on in a second or two. What is the story of food protein, and what does it mean to the average soybean farmer?

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