Energy in Food Production

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THE NEXT TWENTY-FIVE YEARS will be crucial for humanity. For nearly three centuries the world's population has used fossil energy to effectively increase the number of human beings from about one-half billion to the four billion of today (fig. 1). As our numbers increased, fossil energy inputs in food production also increased. Already world food shortages exist; at least half of the world's population is suffering from protein-calorie malnutrition (Borgstrom 1973). The United Nations' World Food Conference held in November 1974 reflects the urgency of the problem.

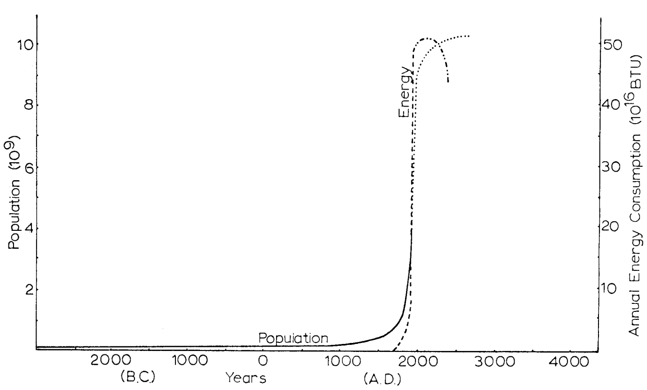


Fig. 1. Estimated world population numbers from 1600 to 1975 (__________) and projected numbers to the year 2250 (......). Estimated fossil fuel consumption from 1650 to 1975 (__________) and projected to the year 2250 (......).

For 990,000 of the approximately one million years that humans have been on earth, total world population numbers were less than that of New York City today. During this period we were hunter-gatherers and were exclusively dependent on solar energy for our food. Each hunter-gatherer required about 10 square kilometers of the natural ecosystem to sustain his or her food needs.

As population numbers increased in the world, we could no longer remain hunters and gatherers and instead turned to a simple form of agriculture called "slash and burn" or "cut and burn," in which trees and shrubs were cut down and burned on site. In this way weeds were killed and at the same time nutrients were added to the soil. Crop production was adequate for approximately two years before soil nutrients were depleted by the plantings. After the depletion of soil nutrients, about twenty years was necessary for regrowth of the forest and shrubs and renewal of soil nutrients.

Cut-and-burn crop technology required few tools (ax and hoe) and a large amount of manpower. In a section of Mexico where cut-and-burn corn culture was investigated, a total of 1,144 hours of labor was required to raise a hectare of corn (table 1). The yield of 1,944 kg/ha provided sufficient food for about four persons subsisting as vegetarians.

Cut-and-burn is the most productive food production technology in terms of food energy returned per energy unit input (a return of 130 kcal of food energy per kilocalorie of energy input[table1]). Of course, the land area required per family system is large, since a twenty-year rotation is required to restore the soil after use. Today, however, most agriculture in the world is a "permanent" type. In the western world, permanent agriculture evolved into high-energy agriculture as numbers and the standard of living increased.

During the past two decades, fossil energy resource use has been necessary to provide the ever increasing numbers of people with food, fiber, public health, and other services. In fact, the consumption of fossil energy supplies has been increasing faster than population numbers. While it has taken the past sixty years for the U.S. population to double, its energy consumption has

Table 1. Energy inputs in corn production in Mexico using only manpower.

Input	*Quantity/ha*	*kcal/ha*
Labor	1,144 hrs	
Ax & hoe	16,500 kcal	16,500
Seeds	10.4 kg	36,608
Total input		53,108
Corn yield (output)	1,944 kg	6,842,880
kcal return/kcal input		128.8

doubled within the past twenty years. More alarming is the fact that while the world population has doubled its numbers during the past thirty years, the world doubled its energy consumption in the past decade. Since our world population is currently four billion and there seems to be no way to prevent it from reaching seven billion during the next twenty-five years, the effect this growth will have on energy supplies is cause for concern.

The total amount of fossil energy used to grow a hectare of corn in 1970 averaged 660 liters of fuel (table 2). Since 1945, the quantity of energy used for nitrogen fertilizer has increased sharply because of increased nitrogen use. In 1970 the energy input for nitrogen fertilizer alone roughly equaled the total energy inputs for corn production in 1945. Nitrogen, machinery, and fuel inputs include two-thirds of all the inputs in corn production today.

Table 2. Energy inputs in U.S. corn production.

Input	*1945*	*1970*
Machinery	539,000*	1,078,000
Fuel	1,400,000	2,060,000
Nitrogen	121,440	1,897,500
Phosphorus	25,600	112,000
Potassium	13,200	147,400
Seeds for planting	77,440	147,840
Irrigation	103,740	187,000
Insecticides	0	82,790
Herbicides	0	82,790
Drying	9,880	296,400
Electricity	39,500	380,000
Transportation	49,400	172,900
Total input	2,379,200	6,644,220
Corn yield (output)	7,504,640	17,881,600
kcal return/kcal input	3.15	2.69

*All figures in kilocalories per hectare.

Based on energy accounting, the return in food energy per input of fossil fuel energy is 2.7 (table 2). The return is one-fiftieth that of producing corn by hand (table 1). Based on current economic values, corn production profits are greater from corn produced with large inputs of today's cheap fossil fuels than from corn produced by hand.

Although we have been emphasizing the use of fossil energy in crop production, the solar energy input is far greater than the fossil energy inputs. During the growing season about five billion kcal (about 500,000 liters of gasoline equivalents) of light energy reaches one hectare of corn (Transeau 1926). The corn plant captures 1.26% of the light energy reaching the field. Hence, in current U.S. corn production about 90% solar energy and only 10% fossil energy are used. Since fossil energy is a nonrenewable resource, our concern is with the 10%

To further complicate energy accounting, the fact is that in the United States most of our corn and other cereal grains are fed to livestock. Of the estimated 4,800 kg of grain per capita used in the U.S., only 300 kg are consumed directly by humans (USDA 1974; USDA 1975). Most of the cereal grains produced are fed to livestock.

The amount of grain used to feed the livestock population can be appreciated when it is known that the livestock population in the United States outweighs the human population more than fourfold (fig. 2). Per capita animal protein consumption in the United States is among the highest in the world. In 1974 annual per capita meat consumption was 114 kg (250 lbs.) or 312 g of meat per day (USDA 1975). Beef consumption amounted to 53 kg; pork, 30 kg; chicken and turkey, 23 kg; fish, 6 kg; and veal and lamb, 2 kg. Per capita milk and milk product consumption was 129 kg and an average of 285 eggs were consumed.

Animal protein is significantly better than vegetable protein in providing the essential amino acids required by man (Burton 1965). Because animals must be fed vegetable protein for their production, the conversion of vegetable to animal protein is costly. Nearly 5 kg of grain and fish protein are fed to livestock (plus a large amount of forage) to obtain 1 kg of animal protein (Pimentel et al. 1975). Translated into energy inputs, approximately ten times as much fossil energy is necessary to produce a unit of animal protein as to produce a unit of plant protein. One of the highest energy costs is for beef protein production. Under feedlot conditions about 78 kcal of fossil energy are required per kcal of

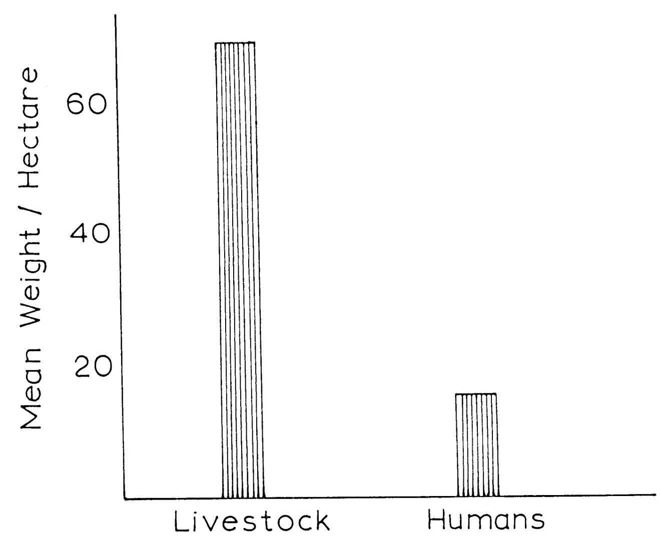


Fig. 2. Livestock biomass significantly outweighs human biomass in the United States.

beef protein produced (Pimentel et al. 1975). Milk protein production requires less than half (36 kcal of fossil energy per kilocalorie of milk protein) the kilocalories for beef protein production (fig. 3). Egg protein is estimated to be about 13:1 or about one-third that of milk.

In the United States, approximately 6 million metric tons of livestock protein are produced each year as a result of feeding an estimated 26 million metric tons of plant and animal protein to these animals (Pimentel et al. 1975). If only grass-fed livestock were produced, livestock protein production would decline from 6 million to an estimated 2 million metric tons. This assumes an effective shift from swine and poultry, which cannot be grass-fed, to more milk, beef, lamb, and goat.

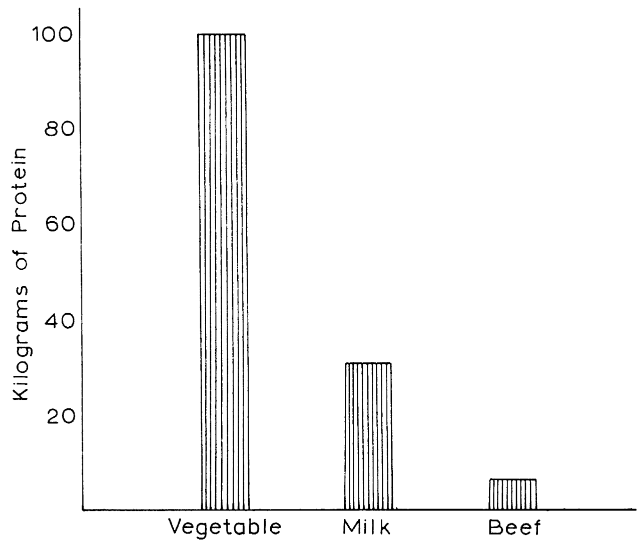
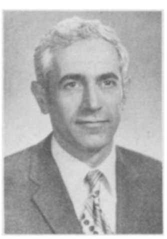


Fig. 3. The conversion of vegetable protein into edible milk and beef protein



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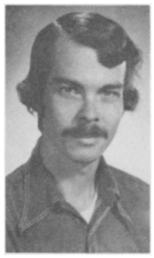

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With the high protein-calorie diet consumed in the United States, along with the energy-intensive systems for food production, processing, distribution, and preparation, an estimated 15% of the energy utilized in our economy is used in the food system. Compared with the energy costs of other sectors of our economy, 15% may not appear to be very much, but in gasoline equivalents, this is approximately 1,250 liters per capita per year, or 262 billion liters annually.

If we were to feed the current world population of four billion on a U.S. diet employing U.S. food system technology, the energy requirement would be 5,000 billion liters of fuel annually. To gain some idea of the energy needs of the future, let us assume the use of known petroleum reserves solely for food, allowing none for transportation, heating or cooling. Our known reserves could feed the present four billion people for a mere thirteen years (Pimentel et al. 1975). Unfortunately, we are faced not only with the need to supply food for seven billion people by the year 2000, but also with the energy input needs of diverse sectors of the world economy.

Today an estimated 25% of the world's energy (including wood) is used for the food system. Based on limited arable land and the world population projection, we estimate that current energy inputs in the food system will have to be increased threefold to meet the food needs of the seven billion humans projected for the year 2000.

Advances in science and technology should help us overcome food shortages, but the real solution to most of the shortages and problems facing us is effective control of human numbers. It is obvious that if we do not control our numbers, nature will.

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Come forth into the light of things,
Let Nature be your teacher. —*William Wordsworth*