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How to Balance Biofuel and Food Production for Optimal Global Health and Nutrition - The Food Crop-Feed Crop-Fuel Crop Trilemma

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"Food is basically a net product of an ecosystem, however simplified. Food production starts with a natural material, however modified later. Injections of energy (and even brains) will carry us only so far. If the population cannot adjust its wants to the world in which it lives, there is little hope of solving the food problem for mankind. In that case the food shortage will solve our population problem." (Steinhardt & Steinhardt, 1974)

1. Introduction

The energy crisis 1973/74 opened our eyes for the close linkage between energy resources and agricultural production. In an analysis of the energy flow in the US Food system, Steinhardt and Steinhardt (1974) found the figures regarding the changes in energy efficiency in food production with time alarming and called for a more holistic view of the energy efficiency in agricultural production. They pointed out that the energy cost to produce animal protein foods such as milk, egg and especially meat is far more than to produce plant foods. To feed the world population with a US type of food system should have required 80 per cent of the world's annual energy expenditure in 1974. They concluded that the most effective way to reduce the large energy requirements of food processing would be a change in eating habits towards less highly processed foods.

Now 40 years later, the linkage between energy resources and food production still exists, but today also from another perspective. It is no longer only the role of agricultural production as energy consumer and the waste of primary resources as result of increased consumption of animal protein that causes a problem. The situation is further stressed by the concomitant increase in the demand of food as result of a growing population. In addition, increased energy needs, especially for transport, makes production of biofuels an interesting alternative for the agricultural sector.

The increased interest to develop biofuel production not only started a conflict of interest regarding land use. It also accentuated a discussion of the impact of indirect land use changes (ILUC) on the environment including increased risks for pollution and climate changes as result of greenhouse gas (GHG) emission (Harvey & Pilgrim, 2011). However, little attention has still been devoted to discuss to what extent changes in dietary habits in order to obtain a better public health situation is in harmony with an increased biofuel production and ILUC. Another perspective is how food and nutrition policy could be involved in the layout for the future direction of the development of biofuel technology.

During the last years a number of reviews have presented an overall picture of the recent development of biofuel technology and its economic, social and environmental impacts. (e.g. Howarth & Bringezu, 2009; Lawrence et al., 2011). Although some of them have linked the increased production of biofuels to a negative effect on food availability and the global food crisis (Fischer, 2009), this is still a matter of controversy.

2. Aims of the chapter

To discuss the changes in global population, socio-economy and lifestyle, food availability and biofuel production, and its impact on primary resources and public health;

To discuss the potentials of better dietary habits to reduce the ongoing increase in indirect consumption of primary resources;

To discuss the potential impact of first and secondary generation of biofuel technology on nutritional intake, public health and food security;

To stimulate an interdisciplinary discussion on the optimal combination of developing a sustainable food production system for optimal health with a sustainable production of renewable energy for the society.

3. Is there food for all?

More than 200 years ago Malthus (1798) presented the problem of imbalance between the population growth vs. growth in agriculture production. However, the balance between food production and population increase (fig 1) illustrates to a certain degree the “hen and egg” question. An increased food production is a prerequisite for population growth, while in a rapidly growing population food shortage leads to malnutrition and death and a “self regulation” of population growth. Nevertheless, all since then, the focus has been on food production as such and to what extent there are enough resources on the globe to feed a rapidly growing world population.

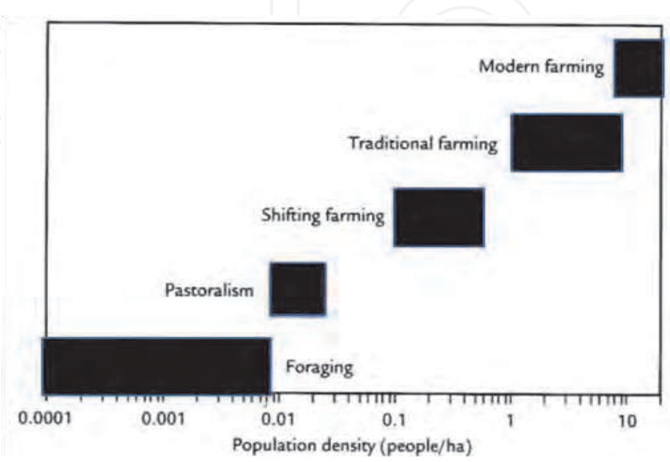

Fig. 1. Carrying capacity of different food systems vs population density (adapted from Smil, 2000)

In the 1960's, i.e. before the energy crisis, Georg Borgström (1965) revived this problem and commented that the situation was aggravated by the high consumption of animal protein, which seriously affected the food balance. The increased use of cereals for feed in animal husbandry resulted in the fact that only 10% of the cereals were consumed directly as food in the human diet in the US population versus 90 % in the Indian population. In addition, life style changes almost doubled the energy consumption per person in the US, which resulted in a three to four-fold higher consumption of primary calories in the food production line in affluent societies compared to that in low income countries. Borgström thus started the discussion whether we can afford to have such a luxury consumption pattern when resources are limited. This was followed up several decades later by Popkin and collaborators (Caballero & Popkin, 2002) when they analyzed the dietary changes during the last century as a result of the socio-economic development and introduced the *nutrition transition concept.*

The multifactorial causes for the imbalance between food production and population growth is consequently not only due to total food production and/or population growth, but also to dietary habits and life style. To solve the population problem with family planning without taking into consideration the role of public health activities to reduce infant mortality is another oversimplification of the problem.

4. The food crop – cash crop dilemma has developed into a food crop – feed crop – fuel crop trilemma

The competition between biofuel and food production represents a revival on an old conflict, i.e. the balance between *food crop* and *cash crop*. Agricultural production initially had the goal to produce food for consumption, and subsistence farming is still the basis for rural development in many low income countries (LIC). However, increased expansion of the monetary system has also increased the interest for producing cash crops for export, e.g. production of coffee and tea, sugar cane, palm oil and tobacco, fish farming of salmon and shell fish. The increased consumption of animal food in addition to the new interest for biofuel has revisited this food crop – cash crop dilemma into a *food crop – feed crop –fuel crop trilemma*.

In addition a new concept has entered the market the last years: *land grabbing* which is a hot political topic of today. Farmland has become a commodity of great interest on the world market. Countries with good economy, which are net food importers but foresee potential problems of food availability in the future, have started to outsource food production. In December 4, 2010 an investor conference was held in Riyadh for high-level delegates from African countries (Against the Grain, 2010). Thus investors from Saudi Arabia are making deals with a number of African countries to control several hundred thousand hectares productive farmland for rice production. Likewise Indian investors have been offered 1.8 million hectares farmland in Ethiopia (IANS, 2011) and China's most powerful agribusiness firms have started to acquire farmland areas in Argentina (Against the Grain, 2011). This has aggravated the competition for land use not only within countries but also between countries. It could be one way to transfer technology between developing nations and give a stimulus to country's food security. But the losers could as well be small family subsistence farmers who cannot compete when prices increase for farmland. The end result may be increased problems of malnutrition among the poor in low-income countries and less food security. What will happen if/when the big agrobusiness firms change their focus from food production to biofuel production?

5. The global food policy meetings

In connection to the energy crises in the beginning of 1970´s, the UN system recognized the global crisis in food production and food availability and the first World Food Conference was arranged by FAO and WHO in Rome 1974 with participants from most UN member states. The starting point was initially to ask for greater engagement in increasing the food production in low income countries (LIC). However, as the increase in these countries was of about the same magnitude as in affluent societies, representatives from LIC raised the question of inefficient use of primary resources in the diet of affluent societies and called for changes in dietary habits in the affluent societies. It was stated that food and nutrition policy was needed in all countries and that dietary habits in the affluent societies should not be exported to low-income countries. Eighteen years later it was followed up by a second meeting called International Conference on Nutrition in Rome 1992 also arranged by FAO and WHO in collaboration. Now the major topic was to get all countries to formulate a food and nutrition policy. This time was the first when also non-governmental organizations (NGO) as well as academics representing the food and nutrition sector were invited to participate in a UN conference for the discussions. Four years later policymakers participated in the World Food Summit in Rome (1996) and it was then stated that food availability is a human right and not only a question of nutritional requirements.

6. The concepts of security, safety and sustainability.

Interestingly the productions of food as well as of biofuels share the same basic problems to be solved: Security, Safety and Sustainability.

6.1 Food security

To have food for tomorrow is the dominant problem for mankind since beginning of history. No political system survives if food security cannot be guaranteed. More people have been killed by malnutrition and its consequences than by bullets throughout the years. Interestingly, the role of food security has increased in the modern society when political conflicts more and more involve the civil population. The responsibility for our politicians to guarantee food availability for its population has increased rather than decreased in the modern society. Increases in food prices and reduced food availability are still the major causes for rebellious movements to bring about the fall of dictatorships. Those societies who have no possibility to guarantee food sustainability for their population and need support from outside are not politically free in the world today. Consequently food power represents a biological and economic weapon in international as well as national conflicts.

6.2 Energy security

This leads to similar concerns. Energy crisis since the 1970´s has clearly illustrated how the development in all societies results in an increased demand for energy. During the 20th century this could be solved by increased production and exploration of fossil energy resources. However we also learned that political power is related to energy security and prompted interest to develop alternatives to fossil fuels in most countries. This in addition to the growing awareness that the fossil resources are limited increased the political interest for biofuel production immensely during the last few decades.

6.3 Food safety

This represents a completely different problem. Sometimes the concept of food safety is misinterpreted as equivalent to food security. However, food safety is not the question to have food for tomorrow; it represents the problem of environmental effects on the food quality. This has so far essentially been discussed in affluent societies. When resources are scarce, there is a tendency to underestimate the potential risks of neglecting the safety problems in the food production sector. The focus of interest is to get optimal yields in food production, often based on increased use of pesticides and biocides. Thus the food safety problem is now an increasing challenge in public health perspectives also in LIC.

6.4 Energy safety

This is related to the climate changes as result of increase in the transport sector, no matter if this is using fossil energy or biofuels. The environmental disturbances as result of greenhouse gas (GHG) emissions is related to increased agricultural productivity and use of land areas, including conversion of forest lands and pastures for increased food and feed crops as well as for biofuels. This calls for political actions including planning of indirect land use changes (ILUC) as well as adequate monitoring tools and sustainability certification (Scarlat & Dallemand, 2011).

6.5 Sustainability

This is a basic and common problem for the food and the energy sectors. The European Union has established some mandatory criteria in their renewable energy directives for biomass, biofuels and bioliquids (European Committee Directive, 2009). The impact on biodiversity, water resources and quality as well as on soil quality should also be evaluated. However there are no criteria for social sustainability, but it is said that the European commission will monitor biofuel consumption and impact on land use, commodity prices and food security.

7. Changes in the global public health panorama

Health statistics seem to be the only objective way to illustrate shortcomings by any political system to solve the problems related to food availability and socio-economic development. Infant and child mortality together with maternal mortality are *the* indicators of an insufficient socio-economic and public health policy. They are also difficult to hide for any type of political system. On the other hand the increased life-span, observed in all types of communities, illustrates not only the effect of decreased infant mortality. It also is a result of the benefits of a functioning health care system. Excellent illustrations of the dynamics in health statistics in relation to socio-economic development on the globe are presented by Hans Rosling and his collaborators on the homepage Gapminder world, which is continuously updated (www.gapminder.org/world).

Three problems dominate the changes in public health during the last 100 years in a global perspective: (i) the (im)balance between population and food availability as result of the population increase; (ii) the changes in the age distribution of the population, and (iii) the socio-economic development leading to changes in life style including changes in dietary habits (described as nutrition transition) as well as increased energy consumption.

Of special nutrition concern are the changes in dietary habits and its impact on public health. The prevalence of nutritional deficiencies has decreased and especially resulted in a drastic reduction in infant and child mortality. However, the diet in affluent societies has caused deleterious long-term effects on public health secondary to increased prevalence of obesity. This has resulted in chronic diseases, e.g. cardiovascular disease, diabetes, cancer, osteoporosis, leading to rapidly increasing costs for health care.

7.1 Population changes

The changes in global population during the last century are not only characterized by an increased number, i.e. a *quantitative* problem. It is also characterized by an increase in mean life span and a concomitant, although slow, decrease in fertility and a profound change in age distribution, i.e. a *qualitative* change. As illustrated in WHO international health statistics (www.gapminder.org/world) it took 40 years in Sweden for life expectancy at birth to increase from 44 to 61 years between 1880 to 1920 in a population of about 4.5 millions. Interestingly it also took 40 years to reach the same increase in life expectancy (from 42 to 62 years) in India with a population of more than 1 billion between 1960 and 2000! Corresponding changes have occurred in a number of LIC as well as in China, sometimes even in shorter time. Thus all countries can be classified as developing societies, and the only difference between affluent and low-income countries with respect to the time it takes to increase life expectancy at birth, is timing. In 1900 only countries in northern Europe and the US showed a life expectancy at birth above 50 years, 100 years later only a few countries in the world showed life expectancy less than 50 years. These changes with time are also excellently illustrated on the Gapminder world website
(www.gapminder.org/world).

7.2 From a population pyramid to a population hexagon

The increased life span has also had an effect on the classical so called population “age pyramid”. A high fertility leading to high percentage of children under 5 years of age, has changed into a population “age hexagon” with lower percentage of infants and young children and an increased percentage of elderly. This results in a change in the public health perspectives on the link between diet and health.

7.3 Malnutrition and public health

With a low life span, e.g. below 50 years, public health was dominated by *malnutrition minus* problems, i.e. energy, protein and vitamin and mineral deficiencies leading to a high infant mortality. An increased life span, e.g. to 75-80 years, in combination with changes in dietary habits, the nutrition transition, as a result of the socio-economic development, has resulted in *malnutrition plus* problems, with obesity, cardiovascular diseases as well as diabetes, osteoporosis and cancer dominating the public health panorama.

If malnutrition minus represents a short-term effect of nutritional problems, malnutrition plus represents long-term effects. This is illustrated when the causes of death in low income countries are compared to those in affluent societies (table 1). In low income countries where high infant mortality exists, the dominating causes of death are infection diseases and maternal mortality. In affluent societies cardiovascular diseases, diabetes and cancer dominate. Interestingly, although nutritional problems are etiological factors for acute as well as chronic diseases they are rarely referred to in the death certificates. This may be one reason why the interest to cope with nutritional deficiencies and disorders in preventive health care is limited in most public health policy programs. Scientific resources for

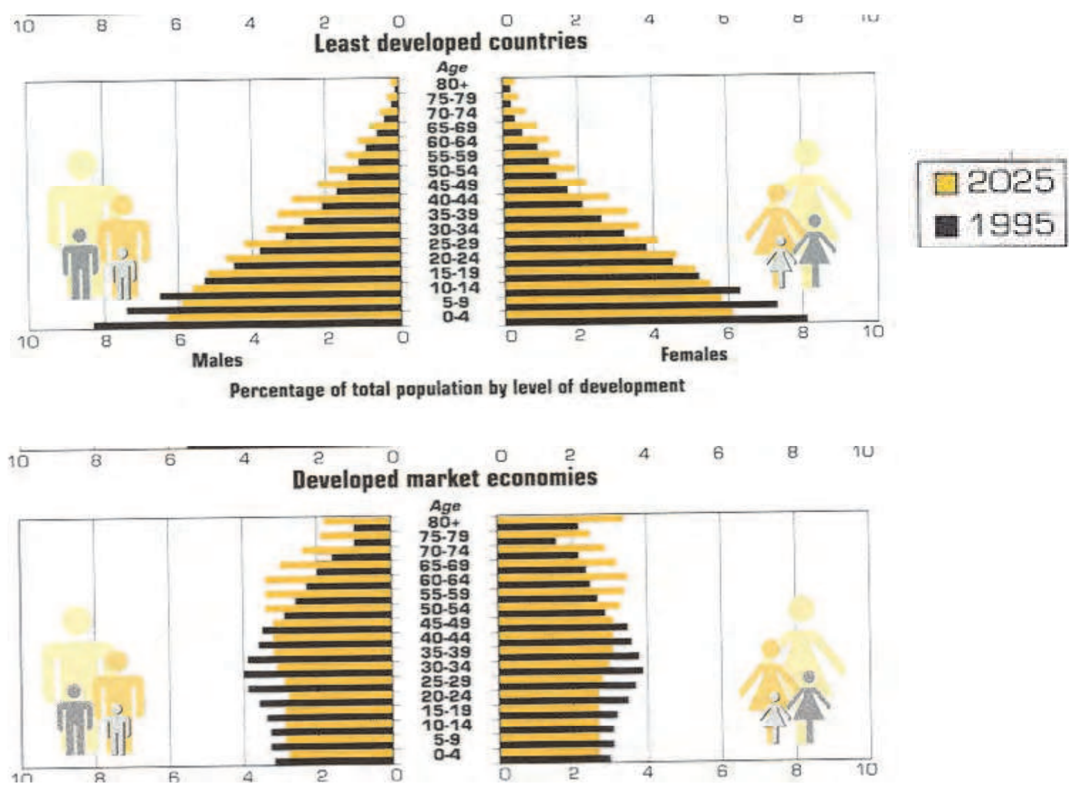

Fig. 2. Age distribution in developed and less developed communities 1995 and 2025 (Source WHO)

treatment of infectious diseases (in low income countries) and cardiovascular diseases, diabetes and cancer (in affluent societies) dominate in relation to preventive health care initiatives for better dietary habits and physical activity programs.

Cause	*Low-income countries*	*Industrialized Countries**
Infectious diseases and parasitic infestations	43	1.2
Cardio-vascular diseases	24.5	45.6
Maternal mortality	10.6	1
Cancer	9.5	21
Respiratory diseases	4.8	8.1
Other causes	7.7	23.1

*Nb Tobacco responsible directly or indirectly to 1/3 of all deaths
(Source WHO Health Statistics)

Table 1. Causes of death in the world (the values refer to per cent of deaths in 1996)

Somewhat provocative it can be said that the loss of manpower due to high infant mortality as a result of *malnutrition minus* is compensated for by high fertility and does not lead to increased public health costs per se. *Malnutrition plus* on the other hand represents a long-term effect which leads to an economic burden on the public health sector due to non-communicable chronic diseases in an increasing elderly population. What is most expensive for the society: High infant mortality or increased public health costs for adults and elderly?

Why is it so that it is easier to convince politicians about the need to develop a policy against malnutrition minus than to counteract the increase of malnutrition plus and obesity in all societies, e.g. in LIC as well as in affluent societies?

7.4 What is the solution: Family planning, food production or public health measures?

It is often argued that family planning will solve the problem. Figure 3 show the relation between fertility (number of children per mother), child mortality (per 1000 births), and life expectancy (years at birth) in 1950 and 2007 respectively. The figures are based on data from some selected industrial and low income countries on the various continents (Africa: Egypt, Kenya, Nigeria, Sudan, Uganda; Asia: Bangladesh, China, India, Indonesia, Japan, Pakistan, Thailand; Europe: Denmark, France, Hungary, Italy, Poland, Russia, Sweden, United Kingdom; Latin America: Brazil, Mexico; Middle America: Costa Rica, Cuba; North America: USA). The figures illustrate the close relation between fertility and child mortality and life expectancy indicating that public health and nutrition programs resulting in lower infant mortality and better health are the best ways to approach the population increase problem. That there is a close relation between child mortality and life expectance at birth is self-explanatory.

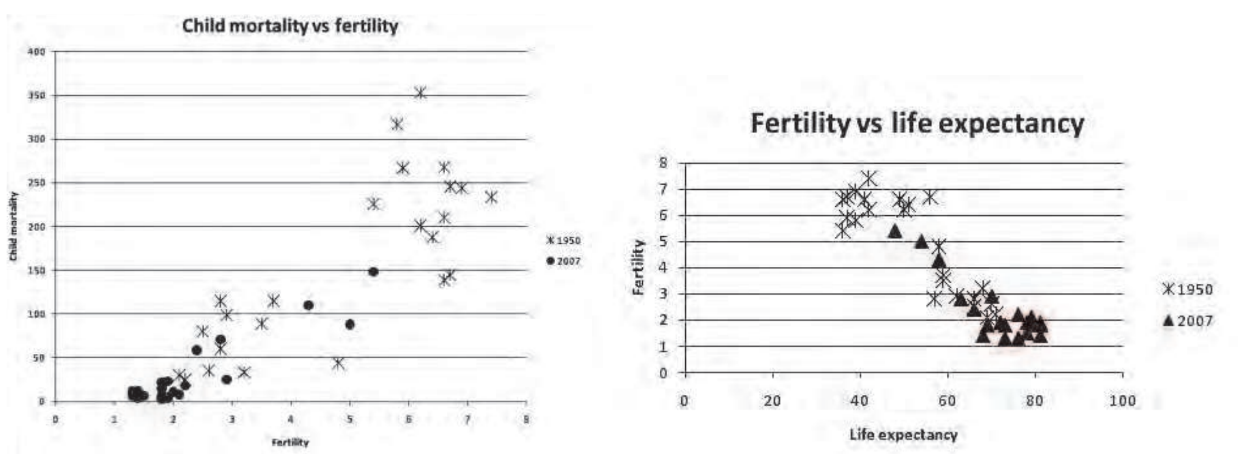

Fig. 3. Fertility versus child mortality and life expectance, respectively in 1950 and 2007. (Source: www.gapminder.org/world)

Figure 4 is based on data from UNFPA (United Nation Population Fund) and illustrates that there has been a reduction in fertility during the last 60 years. Despite this the world population is still presumed to increase although at a lower rate. (The grey shaded area refers to expected changes).

Obviously we must be aware of the fact that there is a lag period before lower fertility will have an impact on population size. Fertility lower than 2 children per woman must however result in a negative trend in world population in the long perspective. However, it is quite obvious from the diagrams that there are reasons to believe that family programs which are not based on actions to reduce infant mortality may be of limited value.

8. Nutrition transition

With the aid of national food balance sheet data from 85 countries Périssé and collaborators already in 1969 made an attempt to relate the general trends of consumption patterns as a

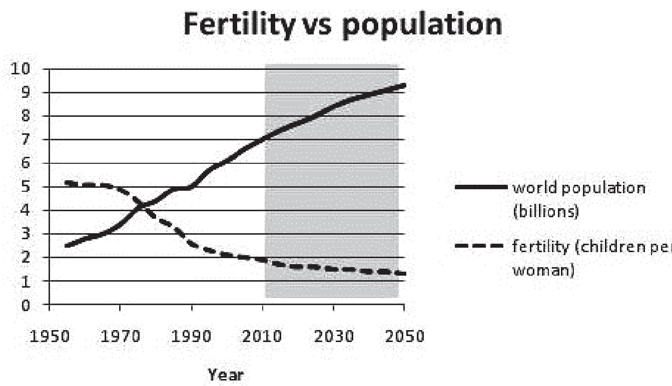

Fig. 4. Trends in fertility and global population during 100 years since 1950 (Source: www.gapminder.org/world)

function of income (figure 5) (Périssé et al. 1969). They could show that although the protein energy percent (E%) was almost the same in low-income countries and affluent societies, the amount of fat and refined sugar constituted much higher E% in the diet of affluent societies leading to increased energy density and reduced nutrient density.

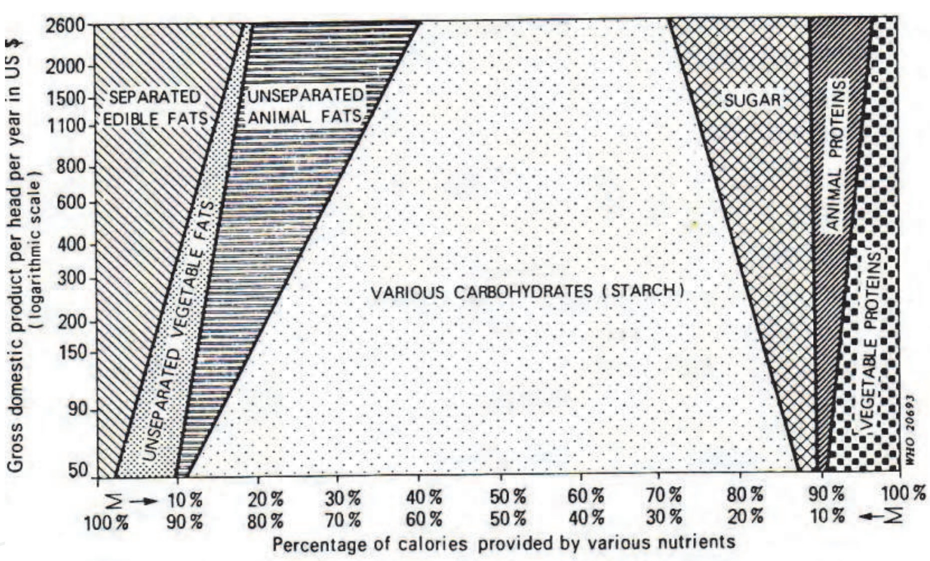

Fig. 5. Absolute and relative intake of energy constituents in relation to socioeconomic factors (Modified from Périssé et al, 1969)

Although 40 years has passed since then, the same difference in energy percentage distribution between macronutrients remains between rich and poor in affluent societies as well as in low income-countries (LIC) and seems to be related to the change in life style in all communities.
Figure 5 illustrates that various carbohydrate (starch) sources (cereals, tubers) represent the major energy source (about 70%) amongst the poor, especially in LIC, while the fat consumption is low (less than 10%). In the affluent societies fat constitutes 35-40% of the energy intake, while the intake of complex carbohydrate only represents about 30-40%. Refined sugar may constitute up to 17%. Refined sugar together with separated edible fat are often characterized as “empty calories” as they do not contain any essential nutrients although they constitute about one third of the energy intake in the diet in affluent societies.

Figure 5 also illustrates the interesting fact, which is often not fully realized, that the energy in the diet derived from protein in LIC represents 10-15 E% and is similar to that in high-income groups. This leads to the following two very essential conclusions: 1) the high protein intake in high-income groups is not due to a higher protein concentration in the food *per se* but to the fact that the total energy consumption is higher; 2) The high prevalence of protein deficiency in LIC is essentially due to a too low total intake of food (i.e. energy), and not primarily due to a low protein content in the food *per se* as often presumed. The latter misconception had for a long time lead to action programs for protein and amino acid enrichment of food. However, the worst off are the poor in affluent societies whose diet is characterized by a high relative amount of empty calories as influenced by the diet in affluent societies, in addition to lack of food. Today priority is given to high yields in agricultural production rather than especially protein rich varieties for human food.

In the affluent societies of today it took thousands of years to develop from hunting and gathering to agricultural production and then another two centuries to become industrialized. Today the same transition in the LIC occurs within a few decades. The socio-economic development has resulted in changes in dietary habits, which is characterized as "nutrition transition" (Caballero & Popkin, 2002). From the nutrition point of view this transition includes not only a better availability of various food items and changes in the dietary pattern, but also in life style, e.g. reduced physical activity, which have further stressed the global food resources. Some of these changes are positive, i.e. a more differentiated food pattern. The reduced physical activity as a result of increased mechanization has reduced total daily energy turnover remarkably, e.g. in Sweden a 30% reduction of total energy turnover as observed from 1930 to 1990 (table 2). The reduced physical exercise in addition to the negative changes in dietary habits including a higher energy density, i.e. increased intake of "hidden fat" and refined sugars, has however increased the risk for the development of obesity if total energy intake is unchanged.

Year/Commodity	*1876-85*	*1886-95*	*1896-1905*	*1906-15*	*1920-29*	*1930-39*	*1950-59*	*1997*
Energy (kcal)	2164	2331	2708	2954	3036	3114	2825	2116
Protein (g)	58	63	74	81	82	87	73	82
Fat (g)	44	49	66	78	94	111	120	82
Protein (E%)	11	11	11	11	11	12	11	16
Fat (E%)	19	20	23	25	29	33	39	34
Carbohydrate (E%)	70	69	66	64	60	55	50	47

Table 2. Intake of macronutrients in Sweden 1876 – 1997. (Source: Swedish Food statistics)

8.1 Various patterns of nutrition transition

Popkin and his collaborators (Caballero & Popkin, 2002) described five patterns developed during the nutrition transition (table 3). The majority of the affluent societies still belong to the pattern 4 while the public health try to stimulate the dietary changes to be more optimal for health as in pattern 5. The question is now to what extent the dietary changes in the LIC can develop directly to pattern 5.

Transition type Behaviour profile	*Pattern 1 Collecting food*	*Pattern 2 Famine*	*Pattern 3 Receding famine*	*Pattern 4 Food surplus society*	*Pattern 5 Healthy diet concept*
Diet	Varied diet (plants, wild animals)	Cereals dominate	Less starchy staples, more fruit, vegetables, animal protein	More empty calories (fat, refined sugar); processed food introduced	Less fat, sugar and processed food; more starchy staples, fruit and vegetables
Nutritional status	Few nutritional deficiencies	Malnutrition minus; vulnerable groups affected	MCH nutrition problems; some deficiencies decrease	Malnutrition plus, Obesity	Reduced obesity improved health
Economy	Hunter-gatherers; subsistence farming	Agriculture, animal husbandry; monoculture; Subsistence farming	Crop rotation, fertilizers and agricultural mechanization; industrial revolution;	Less heavy work; sedentary life; mechanization; increased service sector	Sedentary work dominates; leisure time and leisure exercise increased
Demographic profile	Low fertility; high mortality, low life expectancy; Rural population	High fertility, low life expectancy, high infant and maternal mortality; mostly rural population; small cities	Fertility static; slow mortality decline; Mostly rural population; urbanization begins	Life expectancy increase; rapid fertility decline; increased elderly proportion; urbanization	Life expectancy high (70-80 yrs); increasing proportion of elderly; Less disability; urbanization of rural areas
Morbidity	Infectious diseases; no epidemics	Epidemics; endemic diseases; deficiency diseases	Infection and parasitic diseases; Epidemics; Tb, smallpox, polio; weaning diseases	Chronic diseases related to diet and pollution (CVD, osteoporosis, cancer); infectious diseases declines	Preventive and therapeutic health promotion;
Food processing	none	Food storage begins	Food storage processes; cooking technology	Food transforming technologies	Food and food constituent substitute technologies

(modified from Caballero & Popkin, 2002)

Table 3. The Nutrition Transition pattern characteristics

8.2 Life style changes

Life style changes are characterized not only by changes in dietary pattern, but also by increased mechanization in industry and agriculture and an enormous expansion of the transport system. Mechanization has lead to less heavy work load in agriculture, forestry and industry which has been beneficial for the public health of the population. Interestingly the reduced energy intake as result of less heavy work during working hours is to some extent compensated for by more activities during leisure time. That is one reason why in the international energy recommendations during the last decades the concept of life style was introduced (FAO/WHO/UNU Expert Consultation, 2001). Earlier focus on a reference man or woman and on the energy cost of occupational work has been substituted for by estimates for individuals instead of groups and estimates of total energy turnover now include both occupational work and discretionary physical activities during leisure time. The total daily energy turnover is expressed as a multiple of the basal metabolic turnover per day (which is related to sex, age and body weight) and called physical activity level (PAL). The PAL value is then accepted as indicator of the life style. This is a valuable help to evaluate the optimal energy requirements in man in developing as well as developed communities as it is adapted to differences in life style.

The life style changes have been based on an increased use of essentially fossil energy resources, e.g. coal and oil. There is reason to believe that the same changes in socio-economy standard and lifestyle, which has characterized the affluent societies of today, will occur in other developing societies. Why should not the population in China and India have the same right to have cars and refrigerators as those in the affluent societies when the socio-economic situation gets better? However, not only are conventional energy resources limited, they also lead to environmental problems. There is consequently an urgent need to find sustainable and renewable energy sources which are in balance with a sustainable food production.

9. Nutritional priorities

Under normal conditions body gives priority to cover its *energy needs*. This can be covered from any of the energy-yielding macronutrients (carbohydrate, fat, protein and alcohol). Thus energy need defines the amount of food needed, i.e. a *quantitative* aspect of the dietary intake. When the energy need is not covered from the diet, energy is mobilized from energy-yielding substances stored in the body (glycogen in liver and muscle, fat in subcutaneous tissue and adipose tissue). Adipose tissue is the dominating energy store, but interestingly body protein also constitutes a potential and substantial fraction (about 20% of the total energy store in the body). Nevertheless the body uses carbohydrate as energy source in the first hand to cover acute energy needs. Since blood glucose represents a minor energy resource and the store of liver glycogen, which is available for energy turnover in the body limited, endogenous carbohydrate is produced from catabolism of muscle protein in skeletal muscle during acute energy deficit before energy is mobilized from the fat stores. Protein will be used as energy source, even if protein needs are not met via the diet in an acute energy deficit. This means that energy turnover and protein turnover are closely related.

The *nutrient needs* refer to the specific need of certain nutrients, i.e. protein, trace elements and vitamin, and water. This leads to a *qualitative* aspect of the dietary intake. The requirement of essential nutrients is essentially related to the active cell compartment, the fat free mass. Thus nutrient requirement is related to the body composition which varies with age, sex and body size, as well as to growth and maturation of tissues and organs. The need of specific nutrients is, however, with few exceptions, not related to energy turnover and physical exercise.

9.1 Protein has a two-fold role

Protein need is due to (i) a *specific nutritional role* as source of essential amino acids for protein synthesis i.e. building up, repairing and maintaining tissues; as well as to (ii) *a non-specific role* as an energy-yielding nutrient. If energy needs are not met, protein is used as energy source. Likewise, if more protein is consumed than specifically needed for protein turnover, which is the case in most affluent societies, the surplus is converted through gluconeogenesis and stored as energy, since protein cannot be stored in the body.

9.2 Is there a protein problem and need for increased consumption of animal products?

During the decades after the Second World War, the international society got more and more aware of the magnitude of nutritional problems in the developing world. International agencies concerned with nutrition – WHO, FAO and UNICEF - were beginning to realize the maldistribution of protein rich food of animal origin and the frequency with which young children in low income countries failed to receive weaning foods of adequate protein value to supplement breast milk. The discussion of global nutrition problems was very much focused on the protein gap and in 1955 WHO initiated the Protein Advisory Group (PAG) to form a prestigious scientific advisory body of the UN system on protein-calorie malnutrition (PAG, 1975). In 1971 it prepared a background document and advice for preparation of the "Strategy Statement on Action to Avert the Protein Crisis" as a UN report. In its early years, PAG was focused on potential sources of relatively low-cost protein, e.g. oil seed. Later other more futuristic protein sources were identified and discussed, e.g. leaf protein concentrates, single cell, fish protein concentrates. As long as energy costs for transport and production were more or less marginal, the focus on the global nutrition problems was on the quantitative and qualitative protein intake. However two years later, as a result of the energy crisis during 1973/74, the scenery had completely changed. One now realized that the focus on protein was too narrow in a global perspective and the interest to produce protein concentrates and protein-rich food products almost collapsed. The energy efficiency in protein production was very low especially for various forms of protein concentrates, e.g. single cell protein, leaf protein and fish protein concentrates. Rapidly increasing energy costs, and the awareness that the major problem was not protein intake, but a too low energy intake and lack of food changed the scenery. A provocative article "The protein fiasco" by Mclaren (1974) started a discussion about a complete re-evaluation of the situation and the unnecessary focus on protein concentrates. As long as the energy needs are not met, the addition of protein rich foods represent a waste of resources since protein is then used as energy source. The name of the advisory group was later changed to "Protein Energy Advisory Group".

9.3 Energy crops for human consumption

As stated earlier the body gives priority to cover its energy needs. It is consequently essential to find optimal resources for high energy yields in food production. The global food supply and reserve is usually expressed as total cereal stores (wheat) on the world market, as per cent of annual consumption or as number of days to feed the world population. The importance of roots and tubers for food security and source of income for poor farmers is overlooked. The great importance of introducing potato and cassava for eradication of malnutrition and increased food availability for the poor was illustrated during the 17th century. In 1985, Horton and Fano discussed the edible energy produced by major crops and showed the potentials of tubers and roots. Their role in the 21st century was commented in a report by Scott and collaborators in 2000 (Scott et al, 2000).

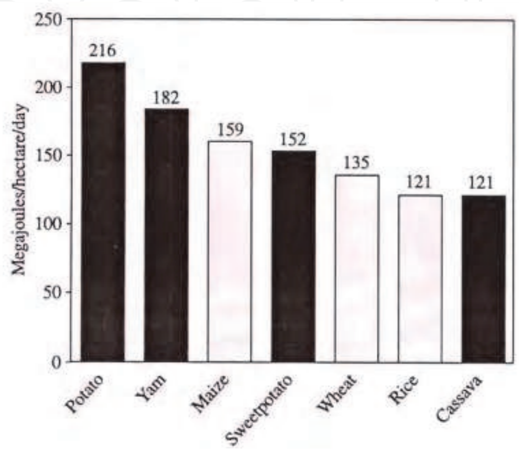

Fig. 6. Edible energy produced by major roots and tubers and cereals (Source: Horton & Fano, 1985)

Even energy yielding crops contain protein, which is often forgotten. In the comment on nutrient transition it was said that the protein energy per cent in the diets is remarkably unchanged. The explanation to this is that protein energy percent is 15% in wheat and maize and only slightly below 10% in rice and potato, as indicated in table 4.

Commodity	*Energy (edible) (kcal per 100 g)*	*Protein energy %*
Cassava	160	3.5
Potato	86	8
Sweet potato	86	7
Yams	118	5
Maize	86	15
Rice	358	7
Wheat	340	15
Meat	201	39
Milk (cow)	61	21
(human)	70	5

Table 4. Energy content and protein energy per cent in some staple foods.

Of special interest is to note the low protein content in human milk. This is partly compensated for by the high quality of milk proteins. The low growth rate in combination with a reduced tolerance for protein as result of immaturity of liver and kidneys in the human newborn has resulted in this adaptation of human milk composition. Such an adaptation is also illustrated by the large differences in milk composition in various mammalian species (Hambraeus, 1979)

The relevant question for a nutritionist in the 21st century is to what extent increased focus on using crops with high energy yields for biofuel production may represent a potential threat for the global food market not only for energy but also protein intake. But it is also essential to argue against the belief that protein requirement is not met by conventional diets and that there is a need for increased meat consumption, protein rich food and/or protein supplements in the affluent society.

10. Is there an optimal diet?

As nutritionist you are often asked to give advice of the optimal diet. This is an almost impossible question to answer, as the human being is a very adaptable object which is not always realized. However, it is impressive to what extent man can adapt to the environmental situation. When we are discussing the concept of an optimal diet the premises must be defined and analyzed. A systems analytical approach must be established where nutritionists, agronomists and those engaged in technical change and innovation within the bioenergy sphere all cooperate in the future direction of the policy for future food and energy production.

When discussing optimal dietary habits in various zones of the globe it is often forgotten that the present staple diets are mainly the result of adaptation to production resources and not necessarily an optimal diet from public health perspectives. This is probably the main reason why milk and dairy products are staple items in the food basket in populations in temperate zones with only one crop per year; ruminants can be fed on meager fields they can also deliver essential nutrients during the winter season. The production resources may also explain why potato so rapidly developed into a staple food in Europe and cassava in the tropical zones during the 17th century. Potato and cassava were both imported from the Alto Plana region in Latin America during the 17th century and represent "import" products. As they represent two crops with high edible energy yield per acre, they have probably saved more lives in poor families in times of famine than most other food items.

In his classical metabolic study, Hindhede already in 1913 (cited by Salaman, 1970) showed that a person could maintain body weight and nitrogen balance with no nutritional deficiencies for more than 100 days when he consumed a diet containing 3000 calories per day based on 2-4 kg potato plus margarine. Thus the content of protein and essential nutrients in a tuber such as potato was enough to cover the nutritional needs. This explains why the introduction of potato with such a high energy yield per area could reduce malnutrition among the poor farmers in Ireland during the 16th century. But the risk to be dependent on a monoculture was also illustrated by the serious famine in Ireland as a result of the potato crop failure during the middle of 19th century (Salaman, 1970).

On the other hand fruits and vegetables are less common in the temperate zones but dominant in the tropical regions. To be a vegan in northern Scandinavia necessitates good transport facilities and socioeconomic welfare as vegetables and fruits must be imported during the winter season often to high prices.

To argue that Paleolithic diet and or the Mediterranean diet is the optimal diet for mankind is an oversimplification of the problem. If high life expectancy is used as indicator of optimal solution of nutrition, the diets of population in Iceland, Japan and Sweden could be indicators. However although they represent populations with the highest lifespan in the world today, their diets are very different from each other. On the other hand socioeconomic factors and prosperity is not a guarantee for optimal health, as indicated by the lower life expectancy in Denmark when compared to two other Scandinavian countries, Norway and Sweden with similar population and socioeconomic situation.

When discussing an optimal future development of biofuel production as well as of food production, the first step must be to define in what perspective they should be optimal:

- Use of primary resources (energy, water, labor, land)
- Socio-economic development (employment, national economy)
- International policy (world trade, global food distribution)
- International solidarity (vulnerable groups in the society, next generation)
- Energy and food sustainability (national as well as international)
- Optimal public health (minimal sickness benefit costs, malnutrition minus and plus)

10.1 Case study

This case study was presented in a seminar for the Agricultural Marketing Board in Sweden in order to illustrate the effect of the nutrition transition in an affluent society such as Sweden on cereal consumption (Abrahamsson, 1979).

Starting from the situation in 1972/73 in Sweden with a production of 1.5 mill tons food cereals (for direct consumption) and 3.6 mill tons feed cereals (for indirect consumption via production of animal products) the potential effect of a reduced production of feed cereals with one mill ton which was substituted for by food cereals, was studied. The reduced consumption of animal products as result of decreased feed production was calculated to be obtained by a 50% reduction in the production of pork, broiler and egg and no intensive beef production. The milk production was left intact (and the related beef production from dairy plants) in order to keep the nutrient intake in children and teenagers more or less intact. In order to keep energy intake the same, the consumption of cereals, potato, roots and legumes in the diet was increased. This led to the following change in food consumption (table 5).

Nutrient	*Decreased consumption of* *Pork (14 kg)* *Broiler (6 kg)* *Egg (6 kg)* *Beef (3 kg)*	*Increased consumption of* *Potato (5 kg)* *Roots (2 kg)* *Legumes (2.5 kg)* *Cereals (12 kg)*	*Net effect*
Energy (kcal)	-54000	+54000	0
Protein (g)	-3400	+1700	-1700
Fat (g)	-4000	+200	-3800
Carbohydrate (g)	-6	+11000	+11000
Calcium (mg)	-5000	+5300	+300
Iron (mg)	-520	+770	+250

Table 5. Calculated effect of decreased feed cereal production on intake of some macronutrients

Although there was increased direct cereal consumption, the net effect was a surplus of 900,000 tons food cereals which could be available for cereal export, or the use of a corresponding production area for other purposes, e.g. cash crops and biofuel.

The obtained change in nutrient intake per capita and day would essentially be a reduced protein intake from 78 to 73 g per capita and day, and a reduction of the animal protein energy percent in the diet from 65 to 56 %. This is however well above the minimal requirement, both with respect to the amount of protein needed and the protein quality.

To what extent could such dietary habits be realistic? The answer is indirectly given in table 6 which shows the food consumption pattern in Sweden in 1939 (before the 2nd world war), 1943 (during the 2nd world war when food production was adapted to self sufficiency with limited resources) and 1982 (when Sweden was a typical affluent society with "modern" dietary habits).

	Consumption g/person/day			
Food item	*1939*	*1943*	*1982*	*Proposed diet*
Milk	530	700	500	660
Cheese	15	10	40	25
Beef & Pork	125	100	165	60
Egg	25	15	35	20
Cereals (wheat&rye)	265	265	175	265
Potato	320	430	230	400
Sugar	130	90	110	100
Butter/Margarine	50	45	65	60
Fish	50	50	75	n.a.

Table 6. Intake of various food items throughout years in relation to proposed modified diet. (The figures refer to g per person and day.)

The table illustrates that the increased direct cereal and potato consumption was well in line with what was consumed during wartime when resources were limited. It also shows the drastic increase in the indirect consumption of cereals as result of increased animal protein consumption during the post war period in an affluent society such as Sweden as result of the nutrition transition.

The question remains: will such changes in dietary habits be accepted by a population in affluent societies? As a matter of fact there were no nutritional deficiencies affecting the public health situation in Sweden in 1943 and less stress on the public health budget due to non-communicable diseases. Why are we still accepting continued increased meat consumption as an unavoidable necessity in affluent societies and on the same time argue that the LIC population should not be allowed to increase their consumption of meat and animal protein products?

Interestingly in 2006 similar discussions were presented by Aiking and collaborators, who calculated that if consumers in developed countries would reduce their protein intake about 30 % and replace meat by vegetable protein, about 80 % of agricultural land used for feed crops could be set free for other productions (Aiking, 2011).

11. Nutritional perspectives on the future of biofuel production

11.1 Development of biofuel technology

The first generation of biofuels comprised production of ethanol from plants containing sugar and/or starch (sugar cane, sugar beet, cereals, cassava) and biodiesel from oilseed crops (rapeseed, sunflower, soybean, palm oil). These could directly compete with the global food supply.

Today the dominant part of liquid biofuel production is based on crops that can also be used for food, e.g. sugar cane, corn and rapeseed. The challenge for expansion of biofuel production is consequently representing a challenge for land area use. This is illustrated by the fact that in 2007 about a quarter of the national corn harvest in the US was used to produce ethanol. The impact of biofuels/bioenergy production on indirect land use change (ILUC) is still controversial. There is a potential for increasing the yields and/or using marginal areas for energy crops. However, probably also energy crops need a certain soil quality and can not only be using marginal land. Thus there is a risk that degraded lands and natural landscapes are restored for biofuel production (Timulsina & Shrestha, 2010).

So far bioethanol and biodiesel produced from a limited number of crops dominate the renewable biofuels for the transport sector. Sugarcane from Brazil and corn/maize from USA are dominating crops for bioethanol. Rapeseed is the dominant crop for biodiesel although oil palm in South Asia and soybean in US and Brazil and sunflower in East Europe are also coming in the focus of increased interest. There are also interesting regional differences in biofuel production. Diesel is essentially the biofuel produced in Europe, while ethanol dominates in Brazil and the US. Another interesting difference is that Brazil, by far the largest producer of ethanol, is producing not only for domestic consumption but is also the world's leading exporter of biofuels. In contrast the biofuel production in the US and Europe is essentially targeted for domestic consumption.

Global production of fuel ethanol has more than doubled from 2004 to 2009. The total production of biodiesel is much smaller but is growing more rapidly than that of ethanol, the annual growth rate being around 50% during the same period.

The second generation of biofuels is based on technologies that convert lignocellulosic biomass (e.g. agricultural and forest residues) or advanced feedstock, e.g. jatropha, microalgae. This production from non-food crops would be much less deleterious for the global food sustainability. On the contrary it could help to get better economy in the agricultural sector, which can then produce both food and fuel together, and increase food availability.

We are still in the beginning of developing biofuel technologies. Priority is presently given to find alternatives for power trains in vehicles and reduce the need for oil import in the transport sector. There are also alternatives based on production of biofuel in other sectors than the agricultural one. Anything from conventional internal combustion energy vehicles using alternative biofuel, i.e. ethanol, methanol, biodiesel, to hybrid and battery powered electric vehicles and fuel cell vehicles are of interest. Of special interest is the potential for energy production from waste products in our consumer society. Furthermore waste products from sewage treatment in industries and the forestry industry may have a great potential, in addition to waste products from the agriculture sector, e.g. rapeseed cakes and straw. From the nutritional point of view these alternatives are of great interest as it means less conflict between production of biofuels and food crops regarding the use of agricultural land.

11.2 A challenge for nutritional science

Changes in life style as a result of socioeconomic development has lead to a nutrition transition which so far has included a deterioration of dietary habits in relation not only to public health but also to the optimal use of primary resources. The concept of optimal intake must be better defined and related to individual needs as well as to food availability and security. This must also take into consideration the optimal use of agricultural resources and land to be balanced in relation to land use for biofuel production. This necessitates a realistic and scientifically sound base for dietary intake recommendations.

Increased production of biofuel may be deleterious for food production if the wrong crops are chosen. But it could also be one of the ways to increase economic power in the agricultural production and thereby help to increase food security. Optimal use of production area also calls for optimal selection of crops under the prevailing circumstances and to increase the efficiency in food production, transport, food industry and food handling. This calls for balance between food production, socioeconomic development and public health perspectives on food and nutrition policy in all countries. This necessitates scientific knowledge and skills in all disciplines and capability for cooperation and an interdisciplinary approach.

11.3 Human capital is the bearing and not the wearing sector in the society! Political power is depending on food policy and energy policy in harmony!

It is high time to reevaluate the role of human capital! Why is it so that the public health sector and educational sector are looked upon as a tearing sector of the society that costs money, and the industrial and economic sector as a wearing sector giving financial support to the society? How can a production function without healthy workers and the society develop without increased knowledge and literacy? How can a society be developed without a democratic balance between producers and consumers? How should a modern society exist without healthy workers and consumers?

The global economic turmoil during the last year has clearly demonstrated the incompetence of the economists and policy makers to handle the situation. In many respects the latest economic crisis was an artificial crisis started by unethical gamblers on the market. It was not a result of a sudden and unforeseen crisis in the availability of primary resources for feeding a population. It was a luxury crisis calling for a reduction of our overconsumption of cars and luxury products, leading to unemployment, malnutrition and public health problems. But the price was not paid by the affluent societies or the rich. Those who had to pay for the mismanagement were the poor people in LIC, who faced increased food prices, with malnutrition as a secondary result of economic mismanagement.

A political system that cannot guarantee food security for its population will never survive, as we have learnt from history and also are reminded of in today's political conflicts. After all it is food and water that represent our basic needs. We do not drink oil neither do we eat dollar or euro notes. Political power must be focused on the human capital and not only on energy or economic power. The best indicators of a healthy population are low infant and child mortality as well as low maternal mortality and a long life span. This is obtained by food availability and sustainability in combination with public health measures for the population. Food power as well as energy power should give priority to meet these goals and not be used as political weapons. New technology to help us reach these goals is expected to be in focus for our scientists. Today it is a challenge to cooperate for developing a biofuel production in balance with food production and optimal use of primary resources and fertile land. If so, the balance between food production and population size will be solved and democracy develop. Otherwise political power will still result in conflicts for control of the world's primary resources and uneven distribution persist between individuals and societies.

12. Conclusion

Today it seems as the dominating global interest is devoted to the energy situation and oil prices and its impact on the global financial situation. This might be the major reason for the increased interest to find alternatives to oil as energy source. It is also an illustration that the debate is still dominated by people from the industrialized world. The real priority for survival and optimal health for mankind from a global perspective is however still food and water. Energy comes much later on the priority list of factors for the survival of mankind. Energy might be a helper but not even the most essential component in the combat against world hunger.

Water and energy resources are prerequisites for food security, but are unfortunately not equally allocated on the globe. During the last decades more interest has been devoted to the global water resources and the impact of human activities on the global water system (Hoekstra & Hung, 2005). The impact of the cost of water on food production and food availability thus represents an additional challenge for the nutritionist, but now also for those engaged in production of biofuels. It has been estimated that food production is a dominant "consumer" of 70% of freshwater and 20% energy resources, respectively (Aiking et al, 2006).

The new interest in production of biofuels is a challenge for all of us. In the enthusiasm to test new approaches to solve global problems, there is a great risk that we do not analyse the long term perspectives and its indirect effects on other markets. The interest in biofuel production is a welcome complement for the development of the agricultural sector, n.b. in case production of biofuel can be based on surplus and waste products, also from the food production sector. A sustainable food production also calls for sustainable energy resources.

The role of the nutritionists is to define the optimal diet for a population based on the specific conditions for food production in various regions and the need to guarantee optimal health for all. The dietary recommendations must be based on objective scientific data and optimal use of available resources, and not on subjective feelings and political fashion. It is obvious that the diet which has developed in the affluent societies of today is by no means optimal, no matter whether we analyze it from the preventive health perspectives, or from the optimal use of primary resources. This calls for interdisciplinary discussions between those engaged in nutritional science, global public health problems and agricultural production, and those engaged to find new means for a sustainable and renewable energy production. Selection of crops and byproducts for renewable energy must be in harmony with the work for optimal diets for optimal health of the global population and vice versa.

The innovative capacity of those involved in developing sustainable energy systems should be combined with the scientific knowledge within the field of nutrition, public health and agronomy in the combat against malnutrition and poverty, as well as against non communicable diseases and waste of global resources. The global resources for food, water and energy in relation to population demands, will dominate national and international policy once and for ever and unfortunately probably be a cause for political unrest also in the future.

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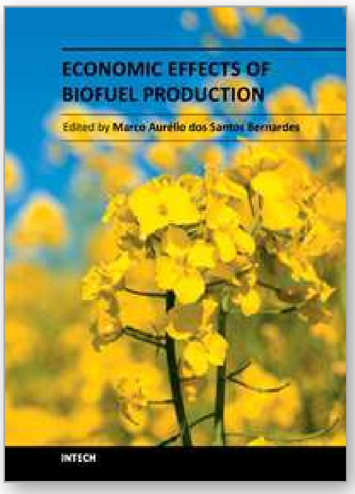
The following websites are recommended for those who are interested to be updated on the ongoing debate on food policy and its relation to health statistics and socioeconomic development.

www.gapminder.org/world;

www.grain-org ;



Economic Effects of Biofuel Production

Edited by Dr. Marco Aurelio Dos Santos Bernardes

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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