Review Article

Traditional food formulation and its future: Examples from South Asia

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Globally, three major problems faced by humanity are population explosion; insufficient production of food (especially so in the South Asian countries); and underdevelopment. These problems are interdependent and need to be tackled soon. Among various factors that limit the world's population, it is undoubtedly the scarcity of food that is most obvious even to a lay person because food is essential for survival. The scarcity of food also brings about recognizably disastrous effects, some of which have already been witnessed. This means that agricultural output, especially those of the waning food crops, must increase enormously over a brief period if the world food situation is to improve. This is a challenge that will confront humanity on the threshold of the centuries to come. In the aforementioned context it would be apt and important to consider innovation of region-specific traditional food crops and exploration of novel foods that will strengthen feeding systems in the present changing times, and contribute to food security and better nutritional values. The present paper has attempted to illustrate some examples from South Asia.

Key words: biotechnology, food safety, genetic engineering, genetically modified food, novel foods, traditional food.

Introduction

An exponential increase in the amount of agricultural production is a necessary counterpart to the exponential growth in human population. In reality, given the present situation for three-quarters of humanity and endemic malnutrition among nearly 1000 million people, the need for an increase in food supplies is urgent, be it traditional or novel or a combination of both. Presently a major attraction of biotechnology investors has been the temptation of new market opportunities and the prospect of revolutionary functional and medical foods and other products that will change our lives.

Food shortages and malnutrition

Nearly three-quarters of humanity are intermittently or permanently faced with a shortage of food. There exists a whole series of stages between a modest food shortage and a state of temporary or endemic famine. This condition is recognized by the appearance of physical disorders linked to deficiency of calories and/or proteins. Children are very vulnerable to malnutrition and the mortality associated with malnutrition. The index of infant mortality is a more appropriate guide to the overall food situation in a country than any other statistical measure (Table 1)

Trends in world food production

The world grain deficit is increasing continuously. Studies have shown that in developed countries with relatively stable populations, the increase in agricultural production will outstrip the needs of those populations, whereas the reverse is true in developing and underdeveloped countries (Table 2)

The adoption of voluntary and efficient programmes of birth control leading to early and massive reductions in the rate of population growth must be substantially improved over the next few decades. It is not enough to just put an end to famine. The food intake of most inhabitants of the Third World (whose daily food quota is still uncertain even when there is no severe shortage) needs to be improved and increased for optimal health and nutrition.

Another recent estimation indicates that the population in 2020 of 7.7 billion people (3.5 billion of whom will be considered in urban areas) can be fed only by significantly increasing the production of cereals (+41%), meat (+63%) and roots and tubers (+40%). Much of this additional food will need to be produced in developing countries for their fast expanding populations.[4–7]

In addition to these factors, an ecological factor that needed to be determined is what increase in world food production can be achieved. Productivity of agricultural ecosystems in turn depends on three principal ecological variables, namely (i) energy, (ii) matter (in the form of inorganic nutrients available) and (iii) the species that make up the total population (nature of plant species, varieties chosen for

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Table 1. Daily intakes of energy and protein for various regions of the world

Region	Energy (kcal/day)	Protein (g/day)	Index of infant mortality per 1000
Developed countries			
Western Europe	3130	93.7	11
North America	3320	105.2	11
USSR and Eastern Europe	3260	99.3	24
Average	3150	96.3	15.9
Third World			
Africa	2190	58.4	120
Far East	2080	50.7	52
Latin America	2530	65.0	65
Middle East	2500	69.3	99
Average	2210	56.0	93

Source: UN International Task Force on Child Nutrition[1] and Population Reference Bureau Data Sheet.[2]

Table 2. Forecasts of world food requirements and agricultural production in 1985 relative to those of 1970

Region	Volume rates of increase (% per year)			Total volume by 1985 (1970 = 100)	
	Food requirements	Agricultural production	Population	Food requirements	Agricultural production
Western countries	1.4	2.4	0.9	124	143
USSR and EasternEurope	1.7	3.5	0.9	130	168
Average	1.5	2.8	0.9	126	151
Third World	3.6	2.6	2.7	170	146
Africa	3.8	2.5	2.9	176	145
South-east Asia	3.4	2.4	2.6	166	143
South America	3.6	2.9	3.1	170	152
Middle East	4.0	3.1	2.9	180	157
Asian communist Countries	3.1	2.6	1.6	158	146
Average	3.4	2.6	2.4	166	146

Source: United Nations Demographic Yearbook.[3]

cultivation, breeds of animal chosen for secondary production). Finally primary and secondary food production of an agricultural ecosystem depends on space, that is, on the total area of good cultivable lands and grasslands available.

The South Asian scenario

The five largest South Asian countries (Bangladesh, India, Nepal, Pakistan and Sri Lanka) have between them 21% of the world's population on only 3% of its land area, making it one of the most densely populated areas in the world (Table 3). Despite the constraints this imposes, South Asia has made impressive strides towards feeding itself over the past century. In the early 1970s, when steeply rising world food prices led to a global food crisis, South Asia was facing this crisis in the form of famine. The widely predicted mass starvation failed to materialize, and the region progressed from a food deficit status in the early 1970s to a food self-sufficient status in the early 1990s, thereby increasing per capita food production. For example, Bangladesh, which is the world's most densely populated agrarian country with a population of 53 million in 1964, was annually importing 3.5 million tonnes of grain. In 1993, the population grew to 115 million, and yet was self-sufficient in food grain.[10]

The Asia-Pacific region has more than 56% of the global population, approximately 73% of the world's farming households, but only 31% percent of the world's arable land.[8] Per capita, arable land availability in the region is only 0.26 ha compared with 1.51 ha in the rest of the world.[8] However, the region is more favourably endowed with irrigation as compared with the rest of the world. It accounts for approximately 61% of the world's total irrigated area and almost one-third of the total arable land is irrigated, compared with one-tenth in the rest of the world (Table 4). This region also accounts for 44.4%, 40.6%, 28.9% and 53.4% of the world's productions of cereals, roots and tubers, fruits and vegetables, respectively.

South Asia's success in countering the 1970s food crisis was due to the green revolution, the widespread diffusion of fertilizer-responsive cereal varieties in areas with access to inputs (i.e. access to hybrid seeds, fertilizers, pesticides, tractors etc.), credit and irrigation. These higher production growth rates were stimulated through the development and

Table 3. United Nations population estimates for South Asia and rest of world

Country/Region	Population (million persons)	Population density per km	Population density per ha arable land	Growth rate 1985–1992 (% per year)
Bangladesh	122.2	938.8	13.9	2.6
India	896.6	301.6	5.4	2.1
Nepal	21.1	154.1	9.1	3.0
Pakistan	128.1	166.1	6.2	3.1
Sri Lanka	17.9	276.9	19.2	1.3
Rest of S.Asia	1185.9	290.9	6.0	2.2
Rest of world	4386.5	34.6	3.8	1.6

Source: calculated from FAO 1993[8] (Table 2) and United Nations 1994[9] (Table 1).

Table 4. Selected indicators of agricultural development in the Asia-Pacific region

Indicators	Asia-Pacific	Rest of world	World	Asia Pacific as % of world
Total population (million), 1991	3034.7	2354.5	5389.2	56.3
Agricultural population (million), 1991	1753.8	656.5	2410.3	72.8
Agricultural land (million ha), 1991	453.3	988.3	1441.6	31.4
Ratio of agricultural land to agricultural population (ha/capita)	0.26	1.51	0.60	43.3
Irrigated land (million ha), 1991	146.5	95.0	241.5	60.7
Irrigated land as percentage of agricultural land, 1991	32.3	9.6	16.8	–
Mineral fertilizer use (NPK kg/ha), 1991	126.6	77.5	92.9	136.3
Agricultural productivity Index (1979/81 = 100), 1991	148.17	114.8	6125.26	–
Cereal production (million tonne), 1992	866.8	1085.4	1952.2	44.4
Cereal yield (kg/ha) 1992	2929	2689	2791	–
Cereal yield growth rate (%), 1982–1992	2.3	1.2	1.6	–
Roots and tubers prod. (million tonne), 1992	238.0	348.1	586.1	40.6
Roots and tubers yield (kg/ha), 1992	14 318	11 148	12 249	–
Fruit production (million tonne), 1992	106.9	262.6	369.5	28.9
Fruit production growth rate (%), 1982–1992	3.6	0.8	1.6	–
Vegetable production (million tonne), 1992	243.4	212.7	456.1	53.4
Vegetable production growth rate (%), 1982–1992	2.9	1.1	2.0	–
Livestock prod. Index (1979/81 = 100), 1991	160	110	126	–
Meat production (million tonne), 1992	57.6	124.5	182.1	31.6
Meat production growth rate (%), 1982–1992	5.8	1.7	2.8	–
Milk production (million tonne), 1992	117.5	401.6	519.1	22.6
Milk production growth rate (%), 1982–1992	4.5	0.1	0.9	–
Fisheries production (million tonne), 1991	44.6	52.3	96.9	46.03
Aquaculture production (million tonne), 1991	13.8	2.8	16.6	83.1
Aquaculture product growth rate (%), 1981–1991	8.6	5.1	7.9	–

Source: FAO 1993.[8]

adoption of improved technologies, coupled with appropriate government policies and programs. Average cereal yield in the region was 2929 kg/ha against 2689 kg/ha in the rest of the world. Growth in cereal production in the region during the past decade accrued essentially through increases in yield, while the cultivable area remained stagnant or even declined. This trend needs to be maintained in the future because there is little scope for a horizontal expansion of arable land.

In a recent assessment by the International Food Policy Research Institute (IFPRI), it was predicted that South Asia's present self-sufficiency in cereals will give way to growing deficits in the early part of the next century. The shortfall is projected to be almost 50 million metric tonnes by 2020.[11] Despite the impressive growth in food and agricultural production during the past 25 years in the region, 523 million people, approximately one-fifth of the region's population, are chronically malnourished.[8] The concentration of malnourished people is considerably higher in South Asia than in East Asia (Table 5).

The population of Asia is expected to grow to 3726 million by the year 2010, comprising approximately two-thirds of the developing world. Although the growth rate will decline, the annual increment will still be more than

50 million people (Table 6). Projected production and demand in South and East Asia will be very tight, and demand will marginally outstrip production (Table 7). This gap will be reflected in the number of chronically malnourished people in the different regions. By the year 2010 the number of malnourished in East Asia will drop to 70 million and in South Asia to 202 million from 252 million and 271 million in 1988/90, respectively.[8] In other words, while the number of malnourished in Asia will decline considerably, the region will still contain approximately 43% of the world's malnourished people (Table 8).

If population density were the only basis for concern about natural resources, the solution would be relatively straightforward. It would begin by accepting that, per capita, due to the scarcity of land and fresh water and the correspondingly high opportunity cost of these resources, South Asia has little comparative advantage in the production of low-value high-volume crops such as cereals. Inevitably this would point towards a move away from cereal production into alternatives such as high-value crops and non-agricultural activities such as manufacturing, alternatives that more closely reflect the opportunity cost of land and

Table 5. Estimates of chronic undernutrition in developing countries

Year	Year	Per capita food supplies (cal/day)	Total population (million)	Undernourished	
				% of total	Million
East Asia	1969/71	2020	1120	44	497
	1979/81	2340	1358	26	359
	1988/90	2600	1558	16	252
South Asia	1969/71	2040	738	34	254
	1979/81	2100	926	31	285
	1988/90	2220	1144	24	271
93 developing countries†	1969/71	2120	2585	36	941
	1979/81	2320	3232	26	843
	1988/90	2470	3905	20	781

Source: FAO 1993.[8]

†Included in the FAO study which accounted for almost all the developing countries. In 1989 these 93 developing countries had 3905 million people of the 3960 million total population for all developing countries of the world.

Table 6. Population projections

	Million		Growth rates (% per year)			
	1989	2010	1970–1980	1980–1990	1990–2000	2000–2010
East Asia	1558	2001	1.9	1.5	1.5	0.9
South Asia	1144	1725	2.3	2.4	2.2	1.8
93 developing countries	3905	5758	2.2	2.1	2.0	1.7
Developed countries	1244	1373	0.8	0.7	0.5	0.4
World	5205	7209	1.9	1.8	1 7	1 4

Source: FAO 1993.[8]

Table 7. Growth rates (% per year) of gross agricultural production and domestic demand (all uses)

Region	Production				Domestic demand			
	Total		Per capita		Total		Per capita	
	1970–1990	1988/1990–2010	1970–1990	1989/1991–2010	1970–1990	1989/1990–2010	1970–1990	1989/1990–2010
East Asia	4.1	2.7	2.4	1.5	4.1	2.8	2.4	1.6
South Asia	3.1	2.6	0.7	0.6	3.1	2.8	0.8	0.8
93 developing countries	3.3	2.6	1.1	0.8	3.6	2.8	1.4	0.9
Developed countries	1.4	0.7	0.6	0.2	1.2	0.5	0.5	0.0
World	2.3	1.8	0.5	0.2	2.3	1.8	0.5	0.2

Source: FAO 1993.[8]

Table 8. Per capita food supplies for direct human consumption (calories/day) and possible evolution of chronic undernutrition

Region	Per capita food supplies(cal./day)			Chronic undernutrition % population			No. persons (millions)		
	1969/1971	1988/1990	2010	1969/1971	1988/1990	2010	1969/1971	1988/1990	2010
East Asia		2600	3060	44	16	4	497	252	70
South Asia	2040	2220	2450	34	24	12	254	271	202
93 developing countries	2120	2470	2730	36	20	11	941	781	637
Developed countries	3200	3400	3470	–	–	–	–	–	–
World	2430	2700	2860	–	–	–	–	–	–

Source: FAO 1993.[8]

water. The export of these products would then be required to pay for cereal imports.

Response to the needs and demands

Several socioeconomic indicators highlight the fact that patterns of food and feed production and use are changing rapidly. The most obvious trends include: (i) change in diet composition, with an emphasis on meat-based diets; (ii) increasing demand for grains; (iii) accelerated rates of urbanization in low-income developing countries; (iv) increased scarcity of water and its inappropriate allocation; and (v) the relationship between the volume of the world cereal stocks, commodity prices and the levels of aid donation.[4,5]

Furthermore, farm yields in parts of Asia are approaching optimum levels. These trends imply: (i) that wider fluctuations in food production and prices are to be expected; and (ii) that vulnerable developing countries will be exposed to higher risks of food insecurity.

While the need for further intensification of agricultural production in the region is clear, the process must change in order to avoid the adverse effects associated with the past. Yield increases in the past three decades were triggered by the widespread use of high-yielding modern varieties, expanded irrigation and increased use of chemical fertilizers. The Asian farmer on average uses 127 kg NPK/ha against 78 kg/ha used by the rest of the world. Greater use of irrigation and mineral fertilizers, which were often not really efficient, had their own negative side-effects such as soil salinity and nutrient leaching. With intensification, the biotic stresses of pests and diseases also increased. Furthermore, approximately 70% of the total cultivated land is rainfed and subject to monsoonal vagaries and other abiotic stresses, and was generally bypassed by the 'green revolution', thus exacerbating inequity.

In order to meet the unprecedented demand for food arising mostly from the burgeoning population and to meet development demands, forests were razed indiscriminately, causing a host of environmental and soil degradation problems. In South-East Asia alone, 5000 ha of tropical forests are cut down every day. The region encompasses megacentres of biodiversity (the raw materials for biotechnology). But, because of wide adoption of a few often interrelated modern varieties, and because of deforestation, the treasure of biodiversity has been eroding fast. Due to increases in soil degradation, increases in genetic vulnerability and intensifying pest incidences, there are increasing examples of plateuing off or even decline of yields, productivity and profitability of major agricultural systems, such as rice–wheat cropping systems in several Asian countries.

Keeping the aforementioned developments and challenges in mind, it is clear that although the process of intensification of food and agricultural production in the Asia-Pacific region must continue in order to feed its people, the ways of enhancing production must be altered. Encroachment on marginal lands and fragile ecosystems, deforestation, erosion of biodiversity and environmental deterioration must not only be avoided, but also reversed, in order to attain enhanced and sustained agricultural production. The 'green revolution', with its strong positive and some negative impacts, was responsible for accelerating food and agricultural production, especially cereal production, over the past 30 years or so. At this juncture the intensification of biotechnology is considered by many to be the means of triggering the next green revolution.

The ecological impacts of doubling food production are soil pollution, soil degradation, erosion, water scarcity, climate change, biodiversity loss and poverty in rural areas. Although soil degradation and water-related problems represent serious constraints, the drive for agriculture sustainability during the 21st century will take place with the need for sustainable populations and levels of material consumption. Ecologically viable intensification of agriculture would be the most suitable approach. The best transition would therefore be to consider alternative solutions adaptable to local specific conditions.

Role and contributions of biotechnology and genetic engineering

Biotechnology promises to bring important changes in plant as well as livestock production. In both fields it will affect all steps of the production chain, from agrochemical inputs and breeding to final food processing. However, it should be viewed essentially as a tool to complement the effectiveness of conventional approaches to solve problems through appropriate capabilities, policies and infrastructures to exploit new and emerging technologies judiciously and rationally and not miss new opportunities.

In the Asia-Pacific region, future increases in agricultural production must accrue essentially through increases in yields. Yields can be increased by (i) preventing the pre- and post-harvest losses; (ii) raising actual yields closer to the current production potential; and (iii) raising the production potential.

Biotechnology is already being applied to one or the other, or all three options for yield increases in several countries of the region, for example *in vitro* culture techniques in potatoes and cassava and plantation crops, haploids in rice, diagnostic kits for disease identification, new and recombinant vaccines, embryo transfer, increased productivity of fishes through sex reversal, polyploidy, hormonal treatments, disease control etc. These techniques should further be refined/standardized and rendered more cost-effective to improve their transfer to and adoption by the majority of small farmers. Plant tissue culture techniques are particularly suitable for Asian settings.

Transgenics for new yields, adaptability and quality, are being designed in the developed countries as well as in several developing countries in the region, which may be commercialized in the future. The first contributions of biotechnology towards higher yield will come through protecting plants from diseases and pests, thereby cutting losses. However, for commercialization of the products under development, resolution and/or establishment of regulatory aspects, particularly biosafety and intellectual property rights should be undertaken simultaneously. The important role of the private sector and the proprietary nature of many of the new products and processes are significant in the context of biotechnology research and development. These features have implications for developing countries using and developing biotechnology. In order to promote equity, mechanisms should be developed and adopted for recognizing and rewarding both formal and informal innovations.[8,12]

Of the major crops of the region, rice is likely to benefit most through the use of biotechnology and is important, because rice is basic to food security. Genetically engineered tungro-resistant rice lines are being engineered at International Rice Research Institute (IRRI). Other expected early successes are transgenic hybrids of Brassica and sunflower, and virus-resistant potatoes and soybeans. Other distinct possibilities are biotechnologically derived biopesticides, biocontrol agents and biofertilizers.

Commercial applications of plant genetic engineering have not yet occurred. Presently, more traditional aspects of biotechnology such as tissue culture have had an important impact, especially in the acceleration of the breeding process for new varieties and in the multiplication of disease-free seed material, and have several advantages as described in the following sections.

Provision of seeds

Plant breeding has been enhanced considerably by *in vitro* development of improved varieties, which are better adapted to a specific environment. The application of tissue culture has several advantages such as (i) rapid reproduction and multiplication of cultivars; (ii) production of healthy cultivars, free of viruses and pathogenic agents; (iii) rapid adaptation and selection of cultivars that are resistant to specific stress factors (e.g. salinity, acid soils etc.); (iv) availability of seed material throughout the year rather than seeds that are subject to the seasonal cycle; (v) possibilities to produce species that are difficult to reproduce or that reproduce and grow slowly; and (vi) improved possibilities for the storage and transportation of germplasm.

Application of tissue culture does not require very expensive equipment, and can be applied easily in developing countries to help improve local varieties of food-crops. In many developing countries better selection from the varieties, which are already available locally, may help to improve food production considerably through traditional knowledge and practices.

Reduced use of agrochemicals

Biotechnology can help reduce the need for agrochemicals, which small farmers in developing countries often cannot afford. It also helps to identify the strains of bacteria that are most suitable for specific crops and soils and to multiply them for large-scale use. Genetic engineering could help develop pest-resistant varieties but this involves more time. Therefore, biological pesticides could be used to help reduce the use of agrochemicals. In addition, improved screening techniques at an early stage may reduce the amount of agrochemicals needed to fight specific diseases.

Increased production

Biotechnology can be used in many ways to achieve higher yields; for example, by improving flowering capacity and increasing photosynthesis or the intake of nutritive elements. In the long term, genetic engineering will also help to increase production of the most valuable components of specific crops. However, the protein content of both staples is low and, for those who lack access to a variety of foods, this may lead to a diet that is not well balanced. Genetic engineering can be used to modify the amino acid composition of plant proteins in order to increase the nutritional value of these staple crops.

Improved harvesting

The cloning of plants can help to reduce the work necessary for harvesting. When individual plants show more uniform characteristics, grow at the same speed and ripen at the same time, harvesting will be less laborious. A reduction in the workload is not only an objective in highly industrialized countries, it can also be very important for small farmers in developing countries, especially women who are already overburdened with many other tasks.

Improved storage

Food shortages would not exist in many countries if the problem of post-harvest losses could be solved. Microbiological reactions by toxicogenic, infective and spoilage microorganisms cause the greatest losses. Biotechnology may contribute to solving these problems. In the future genetic engineering may be used to remove plant components that cause early deterioration of the harvest. Improved storage and better transport of food would increase the quantity of food available and improve the possibilities for a more elaborate division of labour between different districts and regions.

Food processing

Proteins and vitamins are often lost in traditional food processing. Fermentation processes may offer a way to preserve them. Biotechnology can be used for the upgrading of traditional food processing based on fermentation. Biotechnology can also help to eliminate toxic components, either by genetic engineering or through food processing, and inexpensive production of additives that increase the nutritive value of the final product or that improve its flavour, texture or appearance.

Old and new obstacles

The potential of biotechnology for improving food and nutrition in developing countries is vast. Before the development of biotechnology, many new technologies with the potential to improve the world's food situation had been developed, yet many of these techniques have still not been adopted in those countries that could profit significantly from their use. Factors that stand in the way of the application of new technologies in the agriculture sectors of many developing countries include (i) weak linkages between international and national research institutions; (ii) poor communication between national research institutions and farmers; (iii) lack of support measures (credit schemes, regular provision of improved seeds, demonstration plots, marketing outlets); and (iv) landholding structures that dampen the interest of landlords and tenants in introducing new technologies.

Substitution effects

The uneven rate at which different regions in the world adopt the new technologies will lead to large shifts in international trade flows, with products from one country displacing those from other countries. These substitution processes take various forms.

(1) Export crops from developing countries can be replaced by the same crops grown in more temperate climates because these crops can be made more resistant to colder weather.

(2) Export crops can be replaced by the products of other crops (e.g. high-fructose corn syrup derived from maize has become a substitute for sugar produced from sugar cane while fats derived from whey are replacing cocoa butter).

(3) Export cropping can be replaced by 'agricultural' production without soil; that is, by the industrial production of cell cultures in large fermentors (this is becoming the case for high-value, low-volume crops such as pharmaceutical plants as well as flavours and fragrances).

(4) Agricultural exports from some countries will be replaced because other countries will be faster in applying productivity-enhancing biotechnology and thus will become more competitive and will be able to obtain a larger market share. As a result, production of several crops will be concentrated on larger estates in fewer countries.

Animal production

Several countries in the Asia-Pacific region have standardized multiple ovulation and embryo transfer technology and could produce desired sizes of breeding populations. A cooperative regional network on nucleus herd breeding systems should be started. Buffaloes are a monopoly of South and South-East Asia. A cooperative programme in these countries on buffalo biotechnology, including improved efficiency of embryo transfer and initiation of a buffalo genome project would be most appropriate.

Fisheries

Regional capability for production and sharing of fish hormones and vaccines should be improved to promote cost-effective and widespread use of these products. The use of biotechnology for production of fish feed using local resources would further boost and sustain the booming aquaculture industry in the region.

Forestry
In forestry/agroforestry the efficacy and cost-effectiveness of techniques for micropropagation for various purposes should be critically analysed. In some species, such as poplars, biotechnology for pest and disease management is an attractive proposition.

Much biotechnology work in several countries is unfocused. Appropriate priority-setting mechanisms need to be evolved for identifying the most appropriate commodity and approach specific to the agroecological and socioeconomic settings. Work must be diverted to the crops, animals and forest species of importance to the country and region within a country and to the biotic and abiotic stresses these commodities face in those areas. The commodities of high food and non-food values in local settings, but of little economic significance to the capital-intensive markets of industrialized countries, often referred to as 'orphan' commodities, should receive due attention from local biotechnologists. Commodities such as coconuts, oil palm, pigeon pea, jute and buffaloes are almost monopoly commodities of the region and responsibility for their biotechnological improvement should fall primarily to the countries of this region.

Each country should establish a national biotechnology committee consisting of government agencies, universities and scientific academies, the mass media, industry and financial institutions into a symbiotic relationship[13] for sustained progress in application of the new technologies. Governments must allocate adequate budgets to biotechnology and ensure the most judicious utilization of funds according to well-chosen priorities. The private sector is also active in biotechnology in some countries. Appropriate policies and measures must be established to promote private-sector involvement in this field and to forge synergistic links between the private and public sectors.

Few regional cooperative networks on biotechnology are operational in the region, and more may be initiated in the future. One such mechanism may be the continuation of some selected activities under the umbrella of the Asia-Pacific Association of Agricultural Research Institutions (APAARI). Member countries should specifically contribute to agreed activities.

Current trends
It would be highly relevant in the present context to mention some of the steps taken by various national and international agencies to tackle the problems of food production and food safety. This is very much applicable to the South Asian region. The Task Force for the Safety of Novel Foods and Feeds recently conducted a 3-day international conference titled 'New biotechnology foods and crops: science, safety and society' in Bangkok, 10–12 July 2001, with a call for respect for the rights of consumers and the needs of farmers in developing countries in the face of spreading use of new technologies in agriculture. The conference was run in cooperation with the Food and Agriculture Organization (FAO), World Health Organization (WHO), the UNEP, and the Government of Thailand. It brought together 300–350 participants from more than 50 countries, including experts from intergovernmental organizations, scientific institutions, consumer and environmental interest groups, industry, government regulators, policy makers, and representatives from academia and civil society, including participation from all these sectors. The objectives of the conference were as follows: (i) to explore in consultation with international organizations and interested bodies, the way to integrate the best scientific knowledge available into the international processes for consensus building on new biotechnology in relation to food and crop safety; and (ii) to further the concept of open and transparent consultation with an involvement of all stakeholders, including representatives of civil society, supported by shared scientific understanding, which is the key component of a credible food and crop safety system.

It was noted that (i) global problems require global solutions and global consensus based on facts, reason and free and open discussion; (ii) biotechnology has the potential to bring tremendous benefits; and (iii) the public's real concerns must be addressed and there must be greater transparency of information in the labelling of genetically modified (GM) foods. It concluded with recommendations that all stakeholders commit to greater transparency on genetically modified organisms (GMO) and that governments increase their support for independent and publicly funded scientific research into the risks and benefits of GM foods and crops. The working document reflects a summary of some of the common areas of interest that emerged from the discussion and debate.

(1) The importance of considering the issues relating to food safety and human nutrition and the environmental impacts of GM foods and crops was widely recognized.

(2) Environmental impacts will be influenced by the characteristics of the environment and there is likely to be a need for more case/location-specific assessments of genetically modified crops in different countries and regions, perhaps more so than for GM foods, which are less location specific.

(3) Health impacts may be both direct and indirect and both positive and/or negative. The evaluation of health effects should involve toxicological, nutritional and other effects.

(4) Capacity building is important, especially for emerging economies and developing countries. The needs vary among countries, and cover a range of biotechnology-related concerns including biosafety, establishment of regulatory frameworks, risk assessment, technology development and evaluation, intellectual property management and policy making.

(5) Stakeholder dialogue: strengthened capacity would enable more countries and a wider range of stakeholders to participate more effectively in national and international dialogues and fora conducted under the auspices of international agencies. Dialogue needs to be based on common understanding of transparency, openness and inclusiveness. In enhancing transparency greater access for all stakeholders to information in dossiers to support decisions on GM food and crops would be beneficial.

(6) Strengthened capacity would assist countries in implementing the Cartegena Protocol on Biosafety. Although more than 100 countries have signed the protocol, only five have so far agreed to implement it. Some countries are constrained in signing the protocol because they lack the capacity and the human and financial resources to implement the protocol.

(7) International harmonization, standards and protocols: international organizations should continue their important work on harmonization of regulatory approaches and the development of commonly agreed standards and protocols for measuring risk assessment and environmental impact, with wider stakeholder participation.

(8) Science-based risk assessments should be the basis for decision making. There needs to be means for validation of the scientific basis of the risk assessments, in ways that are acceptable to a wide range of stakeholders. Encourage the continued development of robust, science based methods for risk assessments for GM foods and crops, so that government regulators will be able to ensure their safety for human consumption and for release into the environment.

(9) Science can inform the policy and decision-making processes but cannot and should not control it. Science can best contribute when decision-makers frame the questions to which science may be able to provide answers or options.

(10) Independent scientific investigations could contribute to greater understanding of the risks by developing improved methodologies, techniques and protocols for measuring the constituents and the behaviour of GM food and crops. This would also lead to increased credibility of regulatory processes.

(11) Public interest research: some of these investigations need to be publicly funded, to guarantee their independence and public availability of information and public goods, such as those resulting from research on orphan crops. This recognizes that, given the rapid advances in the life sciences, there is a degree of uncertainty as to the long-term and possible unintended effects of GM foods and crops. This requires governments to fund research in the public good, so as to generate publicly available data to set standards for food and environmental safety. These standards developed in the public interest would then inform regulatory decisions on the approval of specific products. These need to be broadly based food safety principles that would govern development of standards for microbiological, chemical, and GM safety of food.

(12) Potential benefits: There are also potential benefits from the safe applications of new biotechnology in addressing specific problems in developing countries. Countries need to have access to new scientific developments, the capacity to assess and regulate new foods and crops, and access to markets for their export produce, where these meet international norms for food safety standards. There is an urgent need to agree on what these standards are for GM food and crops.

The 23rd Session of the Codex Alimentarius Commission, held in June–July 1999 in Rome, decided to establish the Ad Hoc Intergovernmental Task Force on Foods Derived from Biotechnology[14] to develop standards, guidelines or recommendations, as appropriate, for foods derived from biotechnology or traits introduced into foods by biotechnology.[15] The Government of Japan was designated as host Government of the Task Force. The Task Force would complete its work within 4 years (by 2003) through ad hoc consultative meetings. As an outcome of the sessions and consultative meetings it was agreed to evolve an overall work programme including (i) general principle for risk analysis of foods derived from biotechnology (precise title still to be determined); (ii) specific guidance on the risk assessment of foods derived from biotechnology (precise title still to be determined); and (iii) list of available analytical methods including those for the detection or identification of foods or food ingredients derived from biotechnology.

The FAO/WHO Expert Consultations were convened in June/July 2000 (Geneva)[16] and in January 2001 (Rome).[17] The consultations addressed overall aspects of safety assessment of genetically modified foods of plant origin and responded to five specific questions presented by the First Session of the Task Force. The 2001 Consultation specifically addressed the allergenicity of foods derived from biotechnology. The outcome of both consultations was well taken into account during the drafting of the General Principles and the Guideline. The Task Force notes, however, that the responses represent the current state of scientific opinion and are subject to further development, as more scientific information becomes available. The responses of the Expert Consultation to the five questions and the texts of the Proposed Draft Principles and Guidelines form an integral part of the preliminary report. Some of the crucial questions addressed and answered were (i) what overarching scientific principles should be applied to the safety and nutritional assessment; (ii) what is the role, and what are the limitations, of substantial equivalence in the safety and nutritional assessment; are there alternative strategies to substantial equivalence that should be used for the safety and nutritional assessment; (iii) what scientific approach can be used to monitor and assess possible long-term health effects or unintended/unexpected adverse effects; (iv) what scientific approach can be used to assess the potential allergenicity; and (v) what scientific approach can be used to assess the possible risks arising from the use of antibiotic resistance marker genes in plants and microorganisms?

Efforts by the MS Swaminathan Research Foundation at the National Level

The MS Swaminathan Research Foundation under the eminent leadership of Dr MS Swaminathan is trying to address several issues related to the agricultural sector in India, which are also common to South-East Asia. The Foundation has recently been successful in releasing the Food Insecurity Atlas of India, which has been derived using 19 indicators in all relating to three crucial factors, namely (i) food availability in the market, which is a function of production; (ii) access to food, which is related to purchasing power and hence to jobs and livelihoods; and (iii) absorption/ assimilation of food in the body, determined by access to safe drinking water, environmental hygiene and primary health care.[18]

The Foundation has established on-farm community gene banks, seed banks and grain banks in most of its project sites in the country, which is linked to the *ex situ* Gene Bank for conserving the rich traditional/wild germplasm wealth. This activity will be extended to all the other sites shortly. Through continued efforts of Dr MS Swaminathan, India has become the first country in the world to enact legislation that confers rights to both breeders and farmers through the Protection of Plant Varieties and Farmers' Rights Bill, which was recently passed in the Indian Legislation in August 2001. The concept of Farmers' Rights was evolved in the forum of the FAO of the United Nations. This concept aims to accord recognition and reward to the primary conservers of genetic resources, which constitutes the feedstock of the plant breeding and biotechnology enterprises. Steps are underway to convert the provisions of the legislation into field level implementable procedures. The growing and use of traditional and wild foods are being encouraged through effective reward systems to the farmers so as to revive the genetic wealth.

Conclusion

Biotechnology has tremendous potential for increasing food production and improving food processing, although the real impact will be felt only after the year 2000 and it will differ from country to country. Productivity must first increase in developed countries before real benefits can be reaped in developing countries. Where biotechnologies are applied to production destined for domestic markets, 'demonstration effects' can stimulate developments in other countries. In this case there is considerable scope for cooperation among developing countries. However, where the application of this new technology aims to increase productivity in the export sectors, successes in some countries could be at the expense of the market position of others. In such an event, international competition may endanger cooperation among developing countries, which seems necessary for the application of biotechnologies that are specifically suited to their interests.

Evolution of food technology, production and dietary habits, together with changes in trade, will no doubt raise new safety issues and governments would need to be abreast of risk science to assess such changes.[19] The existing food supply has a long history of safe use, although some foods are not safe for some individuals and many foods contain substances that would present health concerns if present above accepted levels. Most foods derived using recombinant DNA techniques are obtained from traditional crops that have usually been modified to exhibit one or a few well-defined traits. The knowledge and experience gained in the use of traditional crops is an important component in the safety assessment of foods derived from such plants.

Safety assessment of whole foods and complex food ingredients requires an approach that differs from the strategy used to assess safety of food additives, pesticides and contaminants. The approach for whole foods is case-by-case, based on an evaluation of multidisciplinary data and information, that are derived from agronomic, genetic, molecular biological, nutritional, toxicological and chemical properties but not limited to these factors alone. Toxicology testing in animals is not routinely employed, but when necessary based on an assessment of available data and information, tests should be designed to address specific issues.

New gene, new protein and other food components, including both intended and unintended changes in the food and steps to reduce the likelihood of adverse, unexpected effects are some of the main points to be considered in the evaluation. In specific cases additional effects (such as antibiotic resistance) may be evaluated. Genetically modified foods and conventional foods have many characteristics in common. In many cases the new food or food ingredient will be nutritionally equivalent to its conventional counterpart. Analytical methods traditionally applied in the evaluation of food constituents such as total protein, fat, ash, fibre and micronutrients may need to be augmented with additional analyses using profiling methods to identify unexpected effects and modified nutrient profiles which may impact on dietary intake and health.

Due to the potential for broad changes in nutrient levels, interactions with other nutrients and unexpected effects, it may be necessary to undertake feeding tests in animals to determine outcomes that result from changes in nutrient profiles and nutrient bioavailability. Nutritional modifications, which are within normal ranges of nutrient variation, might require a less extensive evaluation than those outside normal ranges. The data and information should be of a quality and quantity that would withstand scientific peer review. Safety assessment is designed to identify information on the nature and the severity of any hazards that may be present, allowing appropriate management methods to be defined.

Safety assessment of food and food ingredients obtained using recombinant-DNA techniques does not require new scientific principles or methodology. Similar principles for the assessment of the safety and wholesomeness of GM foods should be applied as practised for conventional foods. Depending on the characteristics of the genetic modifications, specific safety and nutritional aspects are assessed.

The concept of substantial equivalence is well established as an important component in safety assessment, and has been elaborated in several international reports. It is based on the idea that an existing organism (plant) used as food, or as a source of food, can serve as the basis for comparison when assessing the safety for human consumption of a food or a food component that has been modified or is new. There is a broad consensus that substantial equivalence is of value in safety assessment.

Application of the concept of substantial equivalence may lead to the identification of similarities and defined differences in the food and food ingredients. Further safety assessment will be focused on establishing the safety of the differences in the new product such that safety of the food or food ingredient can be established, relative to its comparator. The safety assessment carried out in this way does not provide an absolute safety warrant for the new product. Substantial equivalence can be applied only where there is a suitable comparator. This requires that sufficient data are available or can be generated for the comparator. Where there is no comparator, substantial equivalence cannot be used to assess safety. In such cases safety testing will be required based on the properties of the food concerned.

Current strategies for assessing the safety of foods derived from GM plants are considered appropriate. There are presently no alternative strategies that would provide a better assurance of safety for GM foods than the appropriate use of the concept of substantial equivalence. However, some aspects of the steps in the safety assessment process could be refined to keep abreast of developments in genetic modification technology. Methodologies such as profiling techniques offer a means of providing a more detailed analytical comparison. However, much more developmental work would be necessary before such methods could be validated.

The Expert Consultation report considered that the methodologies for safety evaluation elaborated in the report are adequate to detect and evaluate any possible long-term effects of GM foods.[14] It also considered the issue of long-term effects from the consumption of GM foods and noted that very little is known about the potential long-term effects of any foods. In many cases this is further confounded by wide genetic variability in the population, such that some individuals may have a greater predisposition to food-related effects. It was jointly acknowledged that for GM foods the premarketing safety assessment already gives assurance that the food is as safe as its conventional counterpart. Accordingly it was considered that the possibility of long-term effects being specifically attributable to GM foods would be highly unlikely.

An important aspect of the safety assessment is a consideration of the nature of the introduced gene product. Where there is no history of consumption of the introduced gene product or of the food, a 90-day study will probably be indicated. If such studies show evidence suggesting possible long-term effects (e.g. evidence of cell proliferation), further long-term studies would need to be considered if the development of the product was to continue.

The Consultation was of the view that monitoring to establish links between diet and disease is desirable. However, many chronic health effects are multifactorial and it was recognized that observational epidemiological studies would be unlikely to identify any such effects against a background of undesirable effects of conventional foods. Experimental studies, such as randomized controlled trials (RCT), if properly designed and conducted, could be used to investigate the medium/long-term effects of any foods, including genetically modified foods. Such studies could provide additional evidence for human safety but would be difficult to conduct. In this respect it is also important to recognize the wide variation in diets from day to day and year to year.

The same problems apply to the detection of potential long-term beneficial health effects. Nevertheless, it was recognized that GM foods intended to produce nutritional effects are under development for use in developed and developing countries. In such cases a change in nutrient levels in a particular crop plant may impact on overall dietary intake and it would be important to monitor changes in nutrient levels in such foods and evaluate their potential effect on nutritional and health status.

The potential occurrence of unintended effects is not specific for the application of recombinant-DNA techniques, rather it is an inherent and general phenomenon in conventional breeding. One of the approaches to cope with this problem is to select and discard plants with unusual and undesired phenotypic and agronomic parameters already at an early stage. The practice of consecutive back-crossing is also a major procedure used to eliminate unintended effects. Only in rare cases are these approaches accompanied by analytical screening of defined constituents.

Present approaches to assess possible unintended effects are based, in part, on the analysis of specific components (targeted approach). In order to increase the probability of detecting unintended effects, profiling techniques are considered as useful alternatives (non-targeted approach). Profiling techniques are used at a different level (e.g. genomics, proteomics and metabolomics).

In the future, genetic modifications of plants are likely to be more complex, perhaps involving multiple between-species transfers, and this may lead to an increased chance of unintended effects. In such cases profiling techniques may contribute to the detection of differences in a more extensive way than targeted chemical analysis but they are not yet fully developed and have certain limitations. Having detected differences using profiling techniques, their safety implications of such difficulties will still need to be considered.

An assessment of the potential allergenicity should be made for all GM foods. In the assessment the novel proteins resulting from the inserted gene should be the focus of the investigation in most cases. Possible enhancement of the inherent allergenicity of the host plant food should also be included in the assessment only when the intended effect of the genetic modification involves a significant alteration of the protein content of the food product derived from the host plant. It was recommended to use a decision-tree strategy in the assessment of the potential allergenicity of the novel protein(s). When the transferred gene is obtained from a source with a known history of allergenicity, the assessment should focus initially upon the immunochemical reactivity of the newly introduced protein with IgE from the blood serum of individuals with known allergies to the source of the transferred genetic material. In the absence of evidence of immunochemical reactivity, skin tests with extracts of the novel protein and blinded oral food challenges with the GM food should be conducted on individuals with known allergies to the source of the transferred genetic material, to provide confirmation that the novel protein is not allergenic. This series of tests provides adequate evidence regarding the allergenicity (or lack thereof) of novel proteins expressed by genes obtained from known allergenic sources.

The Consultation Group suggested incorporation of two additional criteria to the decision-tree approach when the genetic material is not known to be allergenic. The level and site of expression of the novel protein and the functional properties of the novel protein should be considered for addition to the list.

Where antibiotic resistance marker genes are present in plants or microorganisms, the possibility of transfer of the genes to pathogenic microorganisms and possible clinical implications must be considered. Horizontal gene transfer from plants and plant products consumed as food to gut microorganisms or human cells is considered as a rare possibility, but cannot be completely discounted. The most important consideration with respect to horizontal gene transfer is the consequence of a gene being transferred and expressed in transformed cells. An important example is the transfer of antimicrobial resistance genes, if it were to occur, from genetically modified foods to gut microorganisms. Important considerations for the assessment of the consequences of the transfer and expression of this gene in transformed cells would be the clinical and veterinary importance of the antibiotic in question, the levels of natural resistance and the availability of effective alternative therapies. In general, antibiotic resistance genes used in food production that encode resistance to clinically important antibiotics should not be present in widely disseminated GMO or foods and food ingredients.

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