



UNITED NATIONS
UNIVERSITY

UNU-IAS

Institute of Advanced Studies

UNU-IAS Report

Food and Nutrition Biotechnology

Achievements, Prospects, and Perceptions



This report was written by

Professor Albert Sasson
UNU-IAS Visiting Professor

UNU-IAS Report

Food and Nutrition Biotechnology

Achievements, Prospects, and Perceptions

Contents

Foreword	4
Executive summary	5
1 The relationship between food and health	6
1.1 Obesity: a world epidemic	6
1.1.1 Obesity among children	7
1.2 Changing eating habits to improve health and well-being	8
1.2.1 Vitamin-A deficiency	9
1.2.2 Artificial sweeteners: the case of sucralose	10
2 Production of healthier food	11
2.1 Functional foodstuffs	11
2.2 Industrial production of healthier foodstuffs	11
2.2.1 The case of long-chain polyunsaturated fatty acids	13
2.3 Biofortification of food crops	13
2.3.1 Rice	14
2.3.2 Wheat	14
2.3.3 Maize	15
2.3.4 Beans	15
2.3.5 Cassava	15
2.3.6 Sweet potato	16
2.4 Regulatory issues and communication policies	16
3 Probiotics and prebiotics	18
4 Nutri-geno-proteo-metabolo-mics era of nutritional studies	19
5 Modification of food tastes and healthier food production	20
6 Correlation of genetic markers with beverage and food quality	21
6.1 Correlation of genetic markers with meat quality	21
6.2 Genetic tagging of aqua-cultural species	21
6.3 DNA fingerprinting of grapevine varieties	21
7 Food safety	23
8 Organic or biological agriculture	24
8.1 Definition and trends	24
8.2 Distribution of organic or “bio” products	24
8.3 Pricing	25
8.4 Certification	25
8.5 Certified denomination of origin	26
8.6 Segregation	27
8.7 Fraud	28
8.8 “Rational” agriculture	28
8.9 The Case of Slow Food: organic farming, eating habits, taste and cultural features	29
References	32

Foreword

This report on biotechnology, food and nutrition is a consolidation of knowledge in potentials, opportunities and developmental processes in applying biotechnology for improvements in human nutrition.

Biotechnology is not alien to the food sector; indeed, its applications in agriculture have formed a major part of the field even in the early days of biotechnology. The Green Revolution of the 1960s demonstrated the immense power of manipulating genes for food production. Continuous innovations in biotechnology have led to the availability of a wide range of services and applications related to food production, processing and marketing. But while society in general has benefited from the rise of biotechnology, its pie benefits remain unevenly distributed, with developing countries getting the lesser share. The promise of biotechnology has to be pursued and utilized to push and strengthen the sustainable development agenda particularly in developing countries. This report shows that this potential could be harnessed if framed by favorable policy environments backed up by research and development, education and public awareness.

This report is part of a series of publications by the UNU-IAS in biotechnology; the report is tailored to offer knowledge at the interface of biotechnology and policy-making in order to link knowledge to development opportunities that might exist at this juncture. It cites progress in various developments in food and nutrition vis-à-vis the prospects of biotechnology as an industry and as governed by existing policies in various countries and international collaborations.

Being an institute for advanced studies, among the objectives of UNU-IAS is to promote dialogues between science and society to inform policy-making. I hope this report would generate interest and new ideas among policy makers, professionals, scientists and other groups who are concerned and hopeful of the promise and potential of biotechnology in human welfare and development.

A.H. Zakri
Director, UNU-IAS

Executive summary

The health of populations depend largely on what they eat; and what and how much populations eat concerns consumers, governments, food manufacturers, consumer advocates, and environmentalists alike. These concerns revolve around issues of their safety, their origins, their health effects – both preventive and therapeutic, their novelty and taste and their adequacy to feed growing populations particularly in developing countries where large portions are either under or malnourished. Current forms of biotechnologies bring enormous potential to addressing these concerns. It can now help not just in growing more varieties of foodstuffs but also in the production of functional foodstuffs, i.e. foods with therapeutic properties; correct some vitamin and micronutrient deficiencies; offer healthier versions of popular foodstuffs without affecting the taste, e.g. sweeteners, bitter or acid suppressors; and can also help trace food origin and authenticity through correlating genetic markers with meat quality, genetic tagging of aquacultural species and even DNA fingerprinting of grapevine varieties. In the areas mentioned, biotechnology has already been making significant inroads in delivering the potential to address the fundamental food and health concerns of a growing world population. Social acceptance for biotechnologies by the public has yet to solidify and spread to reach the acceptance other technologies in other sectors enjoy but the signs are encouraging and industry has so far held on to the current level of reception and acceptance from consumers, while urging governments to give more incentives to help it further.

1 The relationship between food and health

How healthy we are depends largely on what, how and how much we feed ourselves and what we take into our bodies consists of foods that sustain us and drugs that heal our dysfunctions and imbalances. Deep in our bodies, we are hosts to complex microflora, comprising a wide range of different bacterial species that play several roles: supplying their human host with additional value from foodstuffs; protecting against intestinal infections; and contributing to the development of the immune system.

Many health-improving properties of certain foodstuffs are already well known: dairy products may strengthen the immune system; fruits and vegetables contain vitamins that protect humans against infections; meat and fish deliver proteins important for the growth and development of the young body; fibre-rich foodstuffs are important for the intestinal transport of digested food; and several phytochemicals have a long-term protective function against cardiac diseases and, probably, cancer (European Commission, 2002).

Food safety as well as the health benefits from food pervading discussions in every sphere of society have become real, pressing concerns for consumers as they wonder whether the sources and objects of their dining pleasures are fraught with dangers to warrant their fear or constant vigilance.

1.1 Obesity: a world epidemic

In 2000, the World Health Organization (WHO) produced a report that warned governments about a growing epidemic that threatened public health: obesity. In some countries, more than half the population is overweight, and in December 2001 the US surgeon-general, David Satcher, gave a warning that obesity could soon kill as many people each year as cigarette-smoking (The Economist, 2003).

The World Health Organization (WHO) general assembly, held in May 2004 in Geneva, had on its agenda a document entitled 'World Strategy for Food, Physical Exercise and Health'. Through this document, the WHO wanted to draw attention to the non-contagious diseases (cardio-vascular diseases, type-2 diabetes, obesity, cancers, etc.), which represent 60 per cent of world mortality and about 50 per cent of world morbidity. In addition to information and awareness campaigns, the WHO recommended a more stringent regulation on advertisement and labelling of foodstuffs, because 'consumers have the right to obtain correct, standardized and understandable information on the contents of foodstuffs, so as to make enlightened choices'. The WHO's forecasts predicted that cardio-vascular diseases would be the first cause of mortality in developing countries by 2010, a status that is already the case in the industrialized countries. Atherosclerosis – a disease associated with the consumption of foods containing too much fat and sugars, a sedentary lifestyle and smoking – together with type-2 diabetes and obesity are real world epidemics (Benkimoun, 2004a).

The increase in the number of persons suffering from type-2 diabetes is a matter of high concern. The figure of 150 million patients may double in 2005 especially with

the rise of those in pre-diabetic stages, characterized by intolerance to glucose and abnormal glycaemia before breakfast, as well as in the frequency of the metabolic syndrome. The latter is probably three to four times more frequent than the established type-2 diabetes, and it is a combination of obesity (specially an excess of abdominal fat, with an increase of girth), an abnormal content of lipids (particularly triglycerides) in the blood, and hypertension. This syndrome is caused by an excess of body fat, especially in the abdomen, a sedentary way of life and inappropriate eating habits. In addition, the release of great quantities of free fatty acids by the body fatty tissue results in insulin resistance; as the activity of the hormone is inhibited, glucose cannot penetrate into the muscles and consequently glycaemia rises. There is also the release by the fatty tissue of adipocytokines, anti-inflammatory substances that reduce the secretion of another hormone, adiponectin, which normally protects against insulin resistance and inflammation (Benkimoun, 2004a).

Being overweight increases the risk of suffering from several related illnesses and may contribute to an earlier death. Women who are overweight run a risk five times higher than average of developing type-2 diabetes while those who are severely obese have a risk of more than 50 times higher. Obesity is also implicated in cancer: a recent study in USA showed that 14 per cent of cancer deaths in men and 20 per cent in women could be attributed to it. Being overweight is also one of the main causes of heart diseases, the world's major cause of death, above wars, malaria and AIDS (The Economist, 2003).

This problem does not seem less acute in the developing world. Asians and black Africans are even more susceptible to obesity and its related diseases than are Caucasians. For instance, 3 per cent of Chinese and 5.5 per cent of Indians are diabetic, compared with 3 per cent of British people. There are more new cases of diabetes in China and India than there are in the rest of the world put together. This is despite the fact that China was already spending 1.6 per cent of its annual gross domestic product treating non-communicable diseases, mostly obesity-related (The Economist, 2003).

The finger of blame seems to point to eating habits and also at the quality of foodstuffs (with implications for food manufacturing companies). The trend in food manufacturing has been to produce cheaper food, which in some ways could have adverse human health effects. For instance, hydrogenated vegetable oil – vegetable fat made solid by adding hydrogen atoms – is the nutritionists' current enemy. Widely used as a cheap substitute for butter and cream, it is the main dietary source of trans-fatty acids, heavily implicated in heart diseases. Some companies are therefore removing them from their products for fear of lawsuits. Cheap food may also make people eat more, and food companies certainly think giving people more food for their money makes them buy more. That is why portions of manufactured food and soft drinks have been growing in size and volume. Companies are now increasingly under pressure to stop selling to people more food for less money, but it is hard to reverse that trend (The Economist, 2003).

Tasty foodstuffs are generally sugary, fatty and salty. Taste is as much instinct as habit, and once people are used to sugary, fatty and salty foods, they find it hard to give them up. Producing healthier foodstuffs that are also attractive to consumers' tastes could help solve the problem, in addition to education on better nutrition, food consumption habits and regular exercise.

Health food is not a turn-of-the-21st-century invention. In 1985, people gave up caffeine; in 1987, salt; in 1994, fat. Now it is carbohydrates. But contemporary health-food consciousness may have stronger foundations. The need for healthier food may also be a matter of demographics across timelines related to "demographic evolution" as the president of food system design at Cargill, Inc., pointed out. In 1975, there were 230 million over 65 years of age; 420 million in 2000 and 830 million was the estimate for 2025. As people become older, their willingness to spend money on staying healthy increases (*The Economist*, 2003).

Science has also contributed to the growing health-food consciousness. According to New Nutrition Business, a US consultancy firm, in 1996 there were 120 papers on nutrition science in peer-reviewed journals; in 2002, there were over 1000. With more scientific data, regulators (in the USA at least) are more willing to evaluate products and if so found with basis, allow health claims on products; and health claims increase sales. The Atkins diet, during its peak days, which has boosted sales of eggs and meat, and hit potatoes, is one manifestation of consumers' determination to try various ways of programming their eating habits (*The Economist*, 2003).

Supermarkets also cater to this market. For instance, Waitrose's Perfectly Balanced Meals claim no more than 4 per cent fat, very little salt and no 'butylated hydroxanisole or hydroxytoluene' at all; and sales are rising at 20-25 per cent annually. Sales of nutritional supplements have more than doubled in the USA in the six years after the Food and Drug Administration (FDA) liberalized labelling laws. In 2000, sales amounted to \$17 billion and were increasing at 10 per cent a year (*The Economist*, 2003).

In the United Kingdom, by the end of February 2004, a report on public health commissioned by the government cited obesity among its main worries. Previous to that, the Prime Minister's strategy unit floated the idea of a 'fat tax' on foods that induce obesity; and in 2003, the Food Standards Agency – the industry regulation – advocated a ban on advertising junk food to children. Yet the UK government dismissed the idea of a fat tax, and the culture secretary stated she was skeptical about an advertising ban. The health secretary said the government wanted to be neither a 'nanny state' nor a 'Pontius Pilate state, which washes its hands of its citizens' health' (*The Economist*, 2003).

1.1.1 Obesity among children

In France, obesity among children has been increasing since the early 1970s, particularly in the least-privileged social categories. The percentage of overweight schoolchildren has increased from 3 per cent in 1965 to 5 percent in 1980, 12

per cent in 1996 and 16 per cent in 2003. The current figures are those prevailing in the USA during the 1970s, but the rate of increase is similar to that of the US. This illness has become a major challenge to public health and has been considered an epidemic by the French National Institute for Health and Medical Research (INSERM). According to Jean-Philippe Ginardet of the Trousseau hospital in Paris, obesity among children is a frequent, serious and societal disease, difficult to treat, which leads, in the short term, to hypertension, diabetes and increase in the concentration of blood cholesterol. It paves the way for cardio-vascular diseases among adults, i.e. for the first cause of mortality (Blanchard, 2004).

Since 1992, evaluations have been carried out in schools of two cities in northern France. The first evaluation showed that children informed by their teachers had better nutritional knowledge and could therefore adopt better eating habits. The second evaluation, carried out in 1992 and 1997, revealed that within the families substantial change had occurred with respect to a better schedule of meals and to a significant reduction of animal fats in their diet. As a result, between 1997 and 2000, the incidence of obesity in the children in these cities has increased much less: +4 percent among girls and +1 percent among boys compared to the whole region (Nord-Pas-de-Calais) that showed an increase of 95 per cent among girls and +195 per cent among boys. This experimental approach to preventing obesity has led to the launching of a five-year campaign named 'Together, let us prevent obesity among children' by the Observatory of Food Habits and Weight, and the Association for the Prevention and Treatment of Obesity in Pediatrics (Benkimoun, 2004).

Obesity is not a disease that is treated only with the assistance of physicians; it also concerns the family and society as a whole. While there may be basis to claim that the lack of exercise and the increasing time spent watching the television or using the computer, as well as junk food are considered important causal factors, obesity's etiology is not confined to lifestyles and habits. Family histories play an important role too, supported by the fact that 57 per cent of obese children have at least one overweight parent. This underlines the genetic role as well as the conditions attending to the pre- and post-natal periods and to subsequent psychic and social factors in causing obesity (Blanchard, 2004).

New epidemiological studies are needed to better understand the causes of the obesity epidemic. In France, a number of measures have been taken by the Ministry of Health within the framework of their National Programme for Nutrition Health (PNNS), launched in 2001 and the nine priority objectives which aim at stopping the prevalence of obesity among children. These include: the distribution of food and education activities in some primary and secondary schools; setting up a working group on 'food advertisement and the child' with a view to reaching a compromise between the economic interests of the agri-food industry and public health constraints; recommendations to support breastfeeding; publication of a guide for children and teenagers on food and nutrition. Physicians are requested to detect obesity as early as

possible on the basis of reference graphs and a disk for measuring the index of body mass provided to them since November 2003. The WHO guide to measuring this index is as follows: the ratio of body weight (in kg) to height (in meters) raised to the power of 2; a resulting number above 25 is considered overweight and above 30 is “obese.” These tools enable the physician to find out the period within which the accumulation of fat occurs – whether it is between the ages of 5-6 years and or before. With only a 38% success rate of treatment among children, early detection of obesity may improve their chances. (Blanchard, 2004).

In Italy, since the early 1990s a centre has been working on the treatment of obesity among children in Atri, a small town of 11,000 inhabitants in the Abruzzes region. A recent survey in elementary schools showed that 31.6 per cent of children had a weight above the norm and 6.7 per cent of them were obese. Of the latter, the centre’s physicians considered that only 5 per cent of obesity cases could be related to genetic or endocrine causes, while the rest were caused by bad eating habits. It did not seem to be a question of quantity of food but of poor eating habits. Among these habits the physicians listed: the lack of breakfast, too many snacks composed of industrial foodstuffs, lack of, or very little consumption of fresh fruit and vegetables. The absence of exercise was also an aggravating factor (Mola, 2004).

The treatment of obesity cases begins with the involvement of the family. Once a week, children should come to the centre with their parents and sometimes with their grandparents (if the latter are those who cook at home). In the centre’s restaurant, a meal is served to them, containing pasta without fat, fish, fruit and vegetables. Children are not forced to eat meals to which they are not accustomed; they just have to try. The parents also eat the same meals. Then the children meet with the psychologist and nutritionist; the parents follow. Family participation is crucial, because the parents should familiarize themselves with the carefully prepared and measured meals and above all they must understand that the children should not eat quickly, that pasta should not be left aside, that they should not eat while watching television, because this usually causes the child to lose control of what he/she eats. The whole family should reconsider its way of preparing meals and eating them; that is why the centre’s specialists insist that both children and grown-ups have their meals together and eat the same foodstuffs (Mola, 2004).

During the summer, about 40 children between 7 and 10 years old are welcomed in a camp, located in a rural tourist centre seven kilometers from Atri. At the summer camp, children’s nutrition is strictly controlled and physical exercise is a frequent practice, while television is prohibited. The objective is to consolidate the new relationship between children and their food. They learn how to identify foodstuffs through blind-tasting, i.e., they develop their sense of smell and touch through handling them. It has been observed that children who attend the summer camp make remarkable progress with respect to their nutritional health and eating habits. This could be decisive in the treatment of obesity (Mola, 2004)stant vigilance.

1.2 Changing eating habits to improve health and well-being

People are consuming more and more food outside their homes. They eat in bars, restaurants, and other catering enterprises. The latest figures on the consumer barometer indicated that confidence in foodstuffs was undergoing a slow but sustained increase, in the European Union, with the notable exception of fast food. In the Mediterranean countries, the onslaught of fast food has destroyed good feeding habits but instead of the expected high obesity rate, the Mediterranean diet resulted in less cholesterol in the blood, and higher life expectancy. But a study by Eurostat – the Statistics Centre of the European Union – warned that the South was no longer what it was. Not only have the Latins ceased to be slimmer than the Germans and the British. No less than 34.4 per cent of Greek men were overweight, as opposed to 29.5 per cent of their British counterparts and 28 per cent of Germans. The Greek population now possesses the highest proportion of overweight members among countries of the European Union, followed by Spain with 32%. However, the Greeks had the lowest rate of dementia among the over 65’s, and they still enjoy one of the highest life expectancies in the EU, with outstanding defenses against colon cancer, hypertension and heart attacks. This maybe attributed to their high consumption rates for olive oil – 20 litres per person per annum – i.e. seven times more than the Spaniards’ (Sánchez, Bardón, 2004).

Some years ago, attention was drawn to the ‘Mediterranean paradox’: Spain, France and Italy had fewer cardiovascular illnesses than their neighbours in Northern Europe, even though there were no significant differences in body weight. The difference lay in the diet, which includes abundant fruit and vegetables (rich in vitamins and anti-oxidants), olive oil as the main source of fat (as opposed to an excessive use of butter and other saturated fats), more fish (rich in omega-3 fatty acids which protect blood vessels), the reasonable consumption of wine with meals (one glass a day has an anti-oxidant effect and may increase the content of high-density lipoproteins – HDL– in the blood), and of generous inclusions of garlic, onions and nuts. However, in time, the greater consumption of meat and lesser consumption of vegetables, more sauces rather than oil and vinegar dressings, whisky and other spirits instead of wine, soft drinks instead of water, and a sedentary lifestyle have led to more digestive problems, higher blood pressure and more kidney failures and respiratory illnesses. According to the Spanish sociologist and journalist Vicente Verdú, ‘health has declined proportionally with the rise in the economy, and gastronomic ignorance has spread in pace with the cultural revolution (Sánchez Bardón, 2004).

In the United Kingdom, there were signs that the problem of obesity was not necessarily worsening. For instance, while it enjoys the title of being one of the world’s biggest consumers of chocolate, over the four years to 2002, sales of chocolate fell every year: 2 per cent by volume and 7 per cent by value over the period. In February 2004, the new chief executive officer of Nestlé Rowntree described it as ‘a business in crisis’; although the company denied later on that there was a crisis, admitting only that sales of Kit Kat,

its widely-known brand, fell by 2 per cent in 2003. Cadbury Schweppes, the United Kingdom's biggest producer of fattening foodstuffs, stated that five years ago, chocolate made it up to 80 per cent of sales; that was now down to a half. Five years ago, 85 per cent of sold beverages were sweet; that is now down to 56 per cent. The rest was mostly juice. Sale of diet drinks – which made up a third of the sales of fizzy drinks – have been growing at 5 per cent a year, while sales of fattening foodstuffs had been stagnant (*The Economist*, 2004a).

In British supermarkets, people are buying healthier food. According to Tesco's director of corporate affairs, its Healthy Living (lower calorie) range grew by 12 per cent in 2003, twice the growth in overall sales. Sales of fruit and vegetables were growing faster than overall sales, too. That may be partly because fresh produce is becoming more varied, there are more of them available all year round and better supply encourages more demand. Five years ago, Tesco stocked six or seven varieties of tomato, while nowadays it stocks 15. A study carried out by the University of Southampton on a big new supermarket in a poor area of Leeds concluded that after it opened, two-thirds of those with the worst diets now ate more fruit and vegetables (*The Economist*, 2004a).

Cafés and restaurants report an increase in healthy eating too. Prêt-A-Manger, a sandwich chain, stated that sales of salads grew by 63 per cent in 2003, compared with 6 per cent overall sales growth. Even McDonald's, which introduced fruit salad by early 2003, had sold 10 million portions since (*The Economist*, 2004a).

There are also good signs in the area of physical exercise. Gym membership figures suggest that British people at least intend to be less indolent. According to Mintel, a market-research company, there were 3.8 million members of private gyms in 2003, up from 2.2 million in 1998. The overall results of these favourable trends was that the average man became thinner in 2002 while women's BMI was static, at least according to body-mass-index (BMI) which have only began to be recorded in 2002. One year of course does not make a trend, but a decrease in America's weight in 2003, also for the first time, supports the idea that something is changing in the obesity trends of the two of the most developed countries in the world. On the other hand, where the rich lead, the poor tend to follow – partly because the poor become richer over time, and partly because health messages tend to reach the better-educated first and the less-educated later. That happened with smoking, which the rich countries gave up years ago, and the poor are nowadays trying to abandon (*The Economist*, 2004a).

As for government intervention in reducing obesity rates, campaigners for the "fat tax" point out that that this kind of intervention could aid the efforts to reduce obesity rates as government intervention did for smoking. But that may not necessarily be the case with food because consumers now are constantly assailed by messages from companies telling them to lose weight. Also, peer pressure among teens on weight issues may have more impact on teenagers than ministerial action (*The Economist*, 2004a).

However, some forms of government intervention have triumphed. For example, on 8 April 2004, the French parliament examined a bill that aimed at prohibiting automatic machines vending confectionery and soda in schools, and also on setting new rules on the advertisement of foodstuffs during television shows targeted to youth. On 30 July 2004, the French Parliament voted in favour of prohibiting as of 1 September 2005 vending machines in schools. This vote was cheered by 250 pediatricians and nutritionists working in hospitals who earlier on wrote to the minister of health a letter titled 'For a consistent nutrition policy of public health in France'.

The French traditional morning snack has been questioned. In January 2004, the French Agency for Food Sanitary Safety (AFSSA) has published an advice against it; the Agency stated that the concern about compensating food insufficiency among a small minority of children (less than 10 per cent attend school without having had breakfast) leads to an unbalance of the diet of all schoolchildren; the additional food intake causes an excess of calories which leads to an increase in the obesity rate among children (Blanchard, 2004).

1.2.1 Vitamin-A deficiency

More than 250 million children less than five-years old are exposed to the risk of vitamin-A deficiency worldwide. About 500,000 of them go blind annually and 2 million die from this deficiency every year (2003-2004).

To address this deficiency, several strategies can be adopted: medical supplementation, i.e. prescribing vitamin-A pills; the enrichment of food with vitamin A in the agro-industry or when preparing food at the communitary level; and inducing the diversification of food resources that are locally available. The latter strategy was adopted in a pilot project carried out in Burkina Faso, West Africa, in conjunction with promoting the consumption of non-refined red palm oil. From 1999 to 2001, in collaboration with researchers from the University of Montreal Department of Nutrition and from the Health Research Institute at Ouagadougou, Burkina Faso, scientists of the French Development Research Institute (IRD) Unit on Nutrition, Food and Societies, have tested the efficacy of red palm oil on the body's vitamin A as it tested these on mothers and children under five years of age in the centre-east of the country, where this oil is not usually consumed. This oil, well known for its high content of beta-carotene – a precursor of vitamin A – is produced and mostly consumed in the north-west of Burkina Faso (Zagré *et al.*, 2003).

Palm oil has therefore been transported to, and sold on, the sites of the pilot project in order to evaluate its impact on vitamin-A deficiency under conditions where women bought the oil freely and voluntarily. The women were previously informed about the beneficial effects of red palm oil through debates, lectures, theatre performances, etc. (Zagré *et al.*, 2003).

The impact of palm oil was evaluated among women and children, at the beginning and the end of the pilot project through testing the amount of retinol in the blood

serum. Results showed that after two years, the quantity of vitamin A ingested by the mothers and children who consumed red palm oil increased markedly: increase from 41 per cent to 120 per cent of safety inputs among the mothers and from 36 per cent to 97 per cent among the children. Simultaneously, the proportion of mothers and children having a retinol content in the serum lower than the recommended threshold (0,70 $\mu\text{mol/l}$) at the beginning of the study, has decreased from 62 per cent to 30 per cent for the women and from 84.5 per cent to 67 per cent for the children. These results demonstrated that red palm oil was an efficient food supplement in real commercial conditions for combating vitamin-A deficiency (Zagré *et al.*, 2003).

In addition, about half of the women involved in the study modified their eating habits within two years while voluntarily consuming this foodstuff that was new to them. The consumption of red palm oil could therefore be incorporated, like other food items rich in provitamin A (fruit and vegetables), into national programmes for controlling vitamin-A deficiency in Burkina Faso, where the afore-mentioned pilot project is being extended, and in other countries in the Sahelian zone (Zagré *et al.*, 2003).

1.2.2 Artificial sweeteners: the case of sucralose

Sucralose is an artificial sweetener that is arguably the food industry's hottest new ingredient, turning up in everything from the recently launched 'mid-calorie' versions of Coke and Pepsi, to low-carbohydrate ice cream. Yet this sweetener was actually invented in the 1970s. Its success has been the reward for the decades of toil by Tate & Lyle, the British ingredient-maker that patented the substance in 1976 and is currently selling it as a sugar substitute to food manufacturers. Johnson & Johnson, the US health-care group, is selling sucralose for home use under the brand name Splenda (Jones, 2004).

The innovative sweetener is actually chlorinated cane sugar (sucrose). During the manufacturing process, three hydrogen-oxygen groups on a sucrose molecule are replaced by three tightly bound chlorine atoms. The resulting molecule (sucralose) is about 600 times sweeter than sugar and passes through the body without being broken down. The chlorinated agent is sodium chloride, and the underlying chemistry has not put off consumers or food manufacturers. Tate & Lyle has calculated that the worldwide market for 'intense sweeteners' was worth \$1 billion a year at manufacturers' selling prices. In the relatively short time it has been available, sucralose has picked up 13 per cent of this market, giving it second place behind aspartame's 55 per cent, according to Tate & Lyle. Its compatibility with low carbohydrate dieting, not to mention direct praise from the late Dr Atkins himself, has helped (Jones, 2004).

In the US, Splenda is now the leading sugar substitute, having surged ahead of the likes of Equal and Sweet'N Low. IRI, the Chicago-based market research company, revealed that Splenda accounted for 43 per cent of the sugar substitutes bought through US stores – excluding Wal-Mart – to May 2004. Sucralose is also making significant in-roads into the food-ingredients market. Both The Coca-

Cola Co. and PepsiCo., Inc., were using it in their new 'mid-calorie' colas, Coca-Cola C2 and Pepsi Edge, which have been designed to contain half the calories of the regular offering without diluting the sweetness as much as current diet versions. Because it performs better at staying sweet at high temperatures than other artificial sweeteners, sucralose can be used in foodstuffs that previously relied on sugar, such as microwaveable popcorn. Because of its better sweetening performance at high temperatures, McNeil Nutritionals, the Johnson & Johnson's unit responsible for Splenda, was persuaded to introduce a bigger pack size for Splenda to cater for demand from bakeries. This 5lb 'baker's bag' retailed at \$6.99-\$7.99 (Jones, 2004).

Although the original patent dated back to 1976, sucralose had to wait until the 1990s for the first wave of regulatory approvals to come through. In 1991, it was cleared by Canadian authorities. Australia gave it the go-ahead in 1993. Tate & Lyle applied for US approval in 1987. After a long time preparing all the technical information required for the application, US clearance was granted in 1998. In the EU, sucralose had already been available in the United Kingdom, Ireland and the Netherlands but only gained approval for use in all European countries by early 2004 after the publication of an amendment to the EU sweeteners directive (Jones, 2004).

The swelling demand for sucralose led to speculation that the sole manufacturing plant in McIntosh, Alabama, might not cope. The factory used to be jointly owned by Tate & Lyle and McNeil Nutritionals, but the British company took full ownership in 2004 as they redrew their sucralose partnership. In June 2004, Tate & Lyle announced the plant would be expanded at a cost of \$29 million, the work being completed in January 2006 (Jones, 2004).

As for its safety to consumers' health, sucralose has faced claims spread through the Internet, as aspartame had been in its time, that it was not safe, in spite of obtaining official clearance in many countries. However, the Center for Science in the Public Interest, a US lobby group noted for its scepticism of the food industry, declared that there was no reason to suggest that sucralose caused any harm (Jones, 2004).

2 Production of healthier food

2.1 Functional foodstuffs

The concept of 'functional' foodstuffs was defined in Japan by the mid-1980s. Japan had developed diet products with therapeutic properties. In many cases, these were fermented dairy products containing microorganisms having a favourable effect on the digestive tract and its processes. A functional foodstuff should be able to modify one or more organic functions favourably, in addition to its nutritional effect. For these products to be labelled as "nutraceuticals" or "nutraceuticals", their therapeutic role should be demonstrated. These kinds of studies are of particular importance in the case of therapeutic claims against cancer and vascular diseases. A precursor of nutraceuticals is cod liver oil, which has greatly contributed to the control of rickets, a consequence of vitamin-D deficiency. In Europe and the USA, large-scale studies involving tens of thousands of volunteers are being carried out to determine the preventive action of vitamins A- and E-enriched substances and selenium-containing compounds on some pathological conditions resulting from the deficiency of these vitamins and selenium (European Commission, 2002).

In the 1990s, the concept of the potential benefit of functional foodstuffs has become widespread, and the research carried out has led to its first products: an 'anti-cholesterol' oil, derived from maize; a rice deprived of its most allergenic properties; and a grapevine synthesizing more resveratrol (an anti-oxidant well known for its impact on cardio-vascular diseases). By mid-2003, David Sinclair – a pathologist at Harvard University – and colleagues reported in the journal *Nature* on resveratrol, a compound that could lengthen the life of a yeast (*Sacharomyces*) cell by 80 per cent. Resveratrol activates enzymes that prevent cancer, stave off cell-death and boost cellular repair systems. This naturally occurring molecule builds up in undernourished animals and plants attacked by fungi. Wine does not contain much resveratrol and the compound degrades in both the glass and the body. A pill might work better, and a provisional patent has been filed. D. Sinclair seems optimistic about the effect of resveratrol on extending human life expectancy.

During the summer of 1999, Japan published a list of food of specified health use (foshu) including 149 commercial products with a certificate from the Ministry of Health and Well-being. In the USA and Europe, the consumers can buy these pharma-foods or nutraceuticals. The world nutraceutical market value was estimated at \$50 billion in 2004 (Oomah, 2003). On 17 November 1999, Novartis AG announced the launching in Switzerland and the United Kingdom of a first line of nutraceutical products. Even if only several dozens of nutraceuticals are currently known, the nutraceutical industry is steadily poised to grow.

2.2 Industrial production of healthier foodstuffs

Food science and biotechnology can lead to substantial innovations in the production of healthier foodstuffs as well as increased profits by major food companies as in the period 2003-2004. Consider Nestlé (established in 1867). The group is selling beverages (e.g. Nescafé, Nesquik),

mineral water, dairy products, ice-creams (Häagen-Dazs), precooked meals, chocolate, pet food and cosmetic products. In 2002, Nestlé's annual turnover amounted to 87.7 billion Swiss Francs (€57.2 billion), broken down as follows: beverages, including mineral water (23.5 billion Swiss Francs); dairy products (23.2 billion SF); precooked meals (16 billion SF); confectionery (10.2 billion SF); pet food (9.8 billion SF); cosmetic products (5 billion SF). However, in 2003, net profit decreased to 6.2 billion SF, 17.3 per cent less than in 2002, owing to the weak economic growth in Europe and monetary fluctuations. Nestlé's biggest market is Europe with sales of 28.5 billion SF, followed by the American markets (27.6 billion SF). The Asia-Pacific region also became a priority for the group's development with the turnover in that region reaching 14.4 billion SF in 2003.

Nestlé spends 1.35 per cent of sales on research and development – a lot for a food company – and was employing 250,000 persons in 2003-2004 worldwide. It explores the frontiers of nutrition research to determine what people should and should not be eating, to develop products such as milk with added long-chain polyunsaturated fatty acids and non-dairy products fortified with calcium for the lactose-intolerant individuals.

Yakult – a bland, sweet, yellowish drink – is also a good example of industry that made good in healthy drinks. It is produced by the Japanese company Shirota, founded in 1955. Minoru Shirota discovered *Lactobacillus casei shirota* in 1930. The product was launched in Europe in 1994 and since then has spread across the world. It claims the beneficial effects of lactobacilli on the intestinal microflora. It represented a \$2 billion global business, and encouraged competition from other companies (*The Economist*, 2003).

Cargill, Inc., whose core business is commodities, employed 200 food scientists in 2003, up from 20 in 2000. It has developed many products with new ingredients, including Bon Appétit, a raspberry tea with soybean isoflavones, which 'may help promote bone health and relieve some of the symptoms of menopause' (*The Economist*, 2003).

While Kraft Foods and Cadbury Schweppes claimed they were removing some of the trans-fats out of their foodstuffs, PepsiCo, Inc., stated it has taken all the trans-fats out of its Frito-Lay snacks. This move was to a large extent the cause of a 30 per cent boost in fourth-quarter (2003) earnings. The drinks and snacks maker's quarterly profit was also lifted by lower costs associated with its 2001 merger with Quaker Oats. Fourth-quarter earnings were \$897 million, or 51 cents a share, compared with \$689 million, or 39 cents a share, in the same quarter a year earlier. Revenue rose 9.4 per cent to \$8.1 billion. The company continues to expand its snacks line with healthier offerings, e.g. new crisps, using maize oil rather than oil containing trans-fats. Frito-Lay's North American sales grew 6 per cent to \$2.7 billion in the fourth quarter (2003), with volume up a smaller 3 per cent. The unit controlled almost two-thirds of the US snacks market. PepsiCo, Inc., is the world's fourth-biggest agri-food group, behind Nestlé, Kraft Foods and Unilever. In 2003, its turnover reached \$26.971 billion and its net profit was \$4.781 billion. Present in 160 countries, it had 140,000 employees.

The modification of vegetable oils is one of the key areas of plant and crop biotechnology, the overall objective being to increase their content in unsaturated fatty acids (mainly oleic acid) and to decrease that of saturated ones through conventional breeding, induced mutations or genetic engineering. Extensive work has been carried out on oilseed rape (canola), soybeans, peanut and sunflower with good results that led to the commercialization of several products. Palm oil, which contains an equal proportion of saturated and unsaturated fatty acids, in addition to beta-carotene, is also a current research target, particularly of researchers at the Palm Oil Research Institute of Malaysia (PORIM). In addition, replacing triglycerides with diglycerides in vegetable oils render them free of trans-hydrogenated fats and good cooking oils, e.g. 'econa oil' in Japan.

Inulin and oligofructosans refer to a group of fructose-containing carbohydrate polymers (fructans) which, in many plant species, act as protective agents against dehydration and cold temperatures and also offer many health benefits to humans, mainly in the stimulation of the growth of beneficial micro-organisms called bifidobacteria. These bacteria are sometimes used as a probiotic additive to foodstuffs such as yoghurt, as they can defeat harmful bacteria in the intestines and produce compounds with good health benefits. These dietary fructans are also reported to have a lipid-lowering potential. They are not digested in the upper gastro-intestinal tract and therefore have a reduced caloric value. They share the properties of dietary fibres without causing a rise in serum glucose or stimulating insulin secretion (Georges, 2003).

Inulin and oligofructosans can be used to fortify foods with fibre or improve the texture of low-fat foods without resulting in adverse organoleptic effects. Most of these two products currently on the market are either chemically synthesized or extracted from plant sources such as chicory roots. Oligofructosans are shorter chain polymers, highly soluble and provide 30 per cent to 50 per cent of the sweetness of sugar, and also have the other functional qualities of sugars. In formulation, inulin forms a smooth creamy texture, which makes this compound suitable as a fat substitute (Georges, 2003).

We can also cite the work of F. Georges of the Plant Biotechnology Institute (PBI, National Research Council of Canada, Saskatoon, Saskatchewan). He was working on the production of inulin and oligofructosans in separate transgenic plant experiments to compare the efficiency of their fibre production. Oilseed rape (canola), which is a poor producer of inulin and oligofructosans, was used as model system. In particular, the production of two enzymes was to be evaluated: sucrose-1-fructose-1-transferase which adds a fructose moiety to a sucrose molecule, and fructan: fructan fructosyl transferase which continues to elongate the polymer by adding more fructose moieties to the chain. The study showed that both enzymes could be used in conjunction to produce inulins and oligofructosans (Georges, 2003).

Growers of nutraceutical plants need varieties with good agronomic potential and those that are consistent with the varieties in terms of germination time, height and maturity.

Growers will need to be able to guarantee the quality of their natural health-beneficial products. Breeding methods can therefore be used to achieve uniform quality for clinical testing and for product development, as well as to remove these potentially harmful or otherwise undesirable compounds that are produced in the plants along with their therapeutic ones (Ferrie, 2003).

To meet these goals, Alison Ferrie of the Plant Biotechnology Institute (PBI, National Research Council of Canada, Saskatoon, Saskatchewan) was using the doubled haploid technology or "haploidy", which facilitates the development of true-breeding lines. Immature pollen grains, called microspores, were cultured to produce haploid lines, whose genetic stock was thereafter doubled. True-breeding plants were thus produced in one generation, and doubled haploid techniques reduced the time required to develop a new variety by about three to four years. At the NRC-PBI, doubled haploid technology has been developed for oilseed rape (canola) and wheat. It is being applied to a wide range of nutraceutical and herbal species. Over 80 species have been screened for embryogenic response; anise, fennel, dill, caraway, angelica and lovage have shown good potential (Ferrie, 2003). Haploidy could also be combined with mutagenesis to enhance the desirable components or decrease the undesirable characteristics. Mutagenizing single cells (microspores) had definite advantages over seed mutagenesis (Ferrie, 2003).

The new market for healthier foodstuffs attracts both the agri-food giants and pharmaceutical groups, so that the competition is harsh among them and the frontiers are less marked between both kinds of corporations. The competitive advantage of the food industry in this race is that it has a good knowledge of consumers' behaviour, massive marketing strategies while knowing that nutraceuticals should remain tasteful and palatable if these were to be patronized by consumers.

In France, a success story was that of Danone's Actimel, launched in 1995 in Belgium in the form of a small bottle corresponding to an individual dose and commercialized in 15 countries. More than 600 million bottles had been sold worldwide in 1999, including about 100 million in France, where 9 per cent of the households of all socio-professional categories bought Actimel – dubbed the 'morning health gesture'. Others include that of the case of Eridania-Béghin Say in France in 1999, relating to food additives having an impact on cardio-vascular diseases, colon cancer, osteoporosis, diabetes, etc. which sold commercialized powder sugar enriched with 'biofibres', which boosts intestinal microflora and helps the body to naturally resist illness.

Back in Nestlé, they are also carrying out the relevant research-and-development work with the support of its 600-scientist strong nutrition centre, located in Lausanne while in May 1999, in the USA, Australia, and in Switzerland, Unilever with an international nutrition research centre at Vlaardingen, Netherlands, commercialized a 'hypocholesterol' margarine, which could help prevent the accumulation of 'bad' cholesterol. It also aimed to target markets in Europe and Brazil.

In the USA, most agri-food companies (e.g. Campbell, Kellogg's and Quaker Oats) have developed soups, beverages and cereals, which can help digestion and prevent cardio-vascular diseases and hypertension. The US Food and Drug Administration (FDA) has opened the way to nutraceuticals, having labels carrying a health recommendation. On 21 October 1999, the FDA granted to soybeans (25 g of soybean proteins absorbed daily) the clearance to carry the claim 'may reduce cardiovascular risks' on their labels. This request was made by E.I. Dupont de Nemours & Co., Inc., the world's first-biggest producer of soybean products.

Soya sauce and soybean paste are major foodstuffs across Asia. Industrial soybeans undergo a solid-state fermentation process using compliant stainless steel tanks instead of in conventional bamboo trays. They are also inoculated with *Aspergillus oryzae* selected strains that have been developed in Thailand to produce koji in higher yields and of better quality. This technique, developed by a fermentation consortium associating the National Center for Genetic Engineering and Biotechnology (BIOTEC, Bangkok) and the Department of Chemical Engineering of Kasetsart University (Agricultural University, Bangkok), has been successfully applied by the company Chain Co. Ltd., Bangkok, and thereafter adopted by some soya-sauce manufacturers in Thailand. The same company has succeeded in selecting the appropriate strain of *Lactobacillus* to replace the addition of acetic acid in order to enhance the sour taste of soya sauce. The company produces the top quality commercial soya sauce in Thailand – the so-called First Formulation (the Thai Food and Drug Administration categorizes soya sauce into five formulations which differ in protein content).

2.2.1 The case of long-chain polyunsaturated fatty acids

Long-chain polyunsaturated fatty acids are a research focus for nutritionists and food biotechnologists. Their beneficial effect on the functioning of the cardio-vascular system has been initially mentioned since the 1970s in the medical literature. In France, a recent book authored by David Servan-Schreiber – a psychiatrist advocating a 'medicine of emotions' – *Guérir le stress, l'anxiété et la dépression sans médicaments ni psychanalyse* (Curing stress, anxiety and depression without medication or psychoanalysis) has stressed the role of these fatty acids as anti-depression substances. Incidentally, the author of the said book is also a shareholder of a company that sells pills containing these fatty acids (Benkimoun, 2004b).

These long-chain polyunsaturated fatty acids belong to two main categories: omega-3 (first double bound at carbon 3 on the chain) and omega-6 (first double bound at carbon 6 on the chain). Among omega-3 fatty acids, there are the alpha-linolenic acid (ALA) with 18 carbon atoms, eicosapentaenoic acid (EPA) with 20 carbon atoms and docosahexaenoic acid (DHA) with 22 carbon atoms. The human body cannot synthesize the ALA as well as the linoleic acid which is an omega-6 fatty acid. Omega-3 fatty acids are found in rapeseed and soybean oils (linolenic acid), marine animals and human milk (EPA, DHA) [Benkimoun, 2004b].

Food-consumption surveys carried out in France have shown that the consumption of omega-3 fatty acids was insufficient and the ratio of omega 6 to omega 3 was not balanced (this ratio should be between 5 and 10). Although research is being carried out on the precise role of these fatty acids on human health, it is not easy for the public to have a clear view of established scientific facts and amid controversial statements (Benkimoun, 2004b).

Let us look now at what maybe causing confusion among the public as regard the issue of omega-3 fatty acids. It may have begun with the study that revealed lower morbidity and mortality due to cardio-vascular of Greenland's Inuits who consume a lot of fatty fish. In France, the French Agency for Food Sanitary Safety (AFSSA) convened a meeting of experts on the effects of omega-3 fatty acids on the cardio-vascular system. They concluded that the supplementation of daily diet with these fatty acids could have a beneficial impact on the functioning of the cardio-vascular system, as a secondary prevention measure. Morbidity and mortality reduction was indeed significant among the persons who suffered from cardio-vascular or metabolic diseases. However, omega-3 fatty acids did not act on cholesterol; they may act on triglycerides and cell membranes, as well as on blood clotting and heart excitability; they may also have, through prostaglandins (some of these acids are precursors in the biosynthetic pathways of prostaglandins), a positive effect on hypertension (Benkimoun, 2004b). The experts convened by the French AFSSA also warned against the role of the consumption of excessive quantities of omega-3 fatty acids, as they would increase cell susceptibility to free radicals. They recommended a maximum daily intake of EPA and DHA of 2g per day (Benkimoun, 2004b).

Then there are also the claims on the prohibitive effects of omega-3 fatty acids on tumors. To this, the AFSSA experts concluded that all the studies carried out up to 2004 on food habits did not substantiate in humans any evidence indicating that an enrichment of the diet with precursors of omega-3 fatty acids would protect against cancer. However, research work carried out on rats has shown that a diet enriched with omega-3 fatty acids caused a 60 per cent decrease in size of mammary tumours, twelve days after radiotherapy, compared with a 31 per cent decrease in animals fed with a non-enriched diet. Trials are expected to be carried out on humans (Benkimoun, 2004b).

Given the insufficiency of evidence, the benefits of taking Omega-3 pills remain inconclusive. In view of this, the general advice is to consume fish at least twice a week. The same goes for rapeseed oil. This is sufficient to meet the daily needs of omega-3 fatty acids. It is also recommended to feed poultry with rapeseed meal rather than with sunflower meal, because the former is richer in omega-6 fatty acids. Thus, consuming this kind of poultry meat would provide enough omega-6 fatty acids (Benkimoun, 2004b).

2.3 Biofortification of food crops

Biofortification of food crops makes sense as part of an integrated food-systems approach to reducing malnutrition. It addresses the root causes of micronutrient deficiencies, targets the poorest people, and is scientifically feasible and cost-effective. It is a first step in enabling rural households to improve family nutrition and health in a sustainable way.

HarvestPlus is a coalition of CGIAR Future Harvest Centers or Institutes, partner collaborating institutions (e.g. National Agricultural Research Systems in developing countries, departments of human nutrition at universities in developing and developed countries, non-governmental organizations) and supportive donors (The Bill and Melinda Gates Foundation, DANIDA, Swedish International Development Assistance – SIDA, US Agency for International Development – USAID, and the World Bank). The International Center for Tropical Agriculture (CIAT) and IFPRI are coordinating the plant breeding, human nutrition, crop dissemination, policy analysis and impact activities to be carried out at international Future Harvest Centers, national agricultural research and extension institutions, and departments of plant science and human nutrition at universities in both developing and developed countries. An initiative of the Consultative Group on International Agricultural Research (CGIAR), HarvestPlus is a global alliance of research institutions and implementing agencies coming together to breed and disseminate crops with improved nutritive value (biofortification), e.g. with a higher content of iron, zinc and vitamin A. The biofortification approach is backed by sound science. Research on this funded by the Danish International Development Assistance (DANIDA) and coordinated by the International Food Policy Research Institute (IFPRI) led to the following conclusions:

- substantial, useful genetic variation exists in key staple crops;
- breeding programmes can readily manage nutritional quality traits, which for some crops have proven to be highly suitable and simple to screen for;
- desired traits are sufficiently stable across a wide range of growing environments; and
- traits for high nutrition content can be combined with superior agronomic traits and high yields.

Initial biofortification efforts (as of 2005) will focus on six staple crops for which prebreeding studies have been completed: beans, cassava, sweet potatoes, rice, maize and wheat. The potential for nutrient enhancement will also be studied in ten additional crops that are important components in the diets of those with micronutrient deficiencies: bananas/plantains, barley, cowpeas, groundnuts, lentils, millet, pigeon-peas, potatoes, sorghum and yams.

During the first four years (1 to 4) of the project, the objectives are to: determine nutritionally optimal breeding objectives; screen CGIAR germplasm for high iron, zinc and beta-carotene amounts; initiate crosses of high-yielding

adapted germplasm for selected crops; document cultural and food-processing practices, and determine their impact on micronutrient content and bioavailability; identify the genetic markers available to facilitate the transfer of traits through conventional and novel breeding strategies; carry out *in-vitro* and animal studies to determine the bioavailability of the enhanced micronutrients in promising lines; and initiate bio-efficacy studies to determine the effect on biofortified crops on the micronutrient status of humans.

During the following three years (5 to 7), the objectives are to: continue bio-efficacy studies; initiate farmer-participatory breeding; adapt high-yielding, conventionally-bred, micronutrient-dense lines to select regions; release new conventionally-bred biofortified varieties to farmers; identify gene systems with potential for increasing nutritional value beyond conventional breeding methods; produce transgenic lines at experimental level and screen for micronutrients, test for compliance with biosafety regulations; develop and implement a marketing strategy to promote the improved varieties; and begin production and distribution. During the last three years of the project (8 to 10), production and distribution of the improved varieties will be scaled up; the nutritional effectiveness of the programme will be determined; and the factors affecting the adoption of biofortified crops, the health effects on individuals and the impact on household resources will be identified.

The following are the staple crops and notes on their biotech status and potential:

2.3.1 Rice

Rice is the dominant cereal crop in many developing countries and is the staple food for more than half of the world's population. In several Asian countries, rice provides 50 per cent to 80 per cent of the calorie intake of the poor. In South and South-East Asian countries, more than half of all women and children are anaemic; increasing rice nutritive value can therefore have significant positive health impact. Food-consumption studies suggested that doubling the iron content in rice could increase the iron intake of the poor by 50 per cent; germplasm screening indicated that a doubling of iron and zinc content in unmilled rice was feasible. Milling losses vary widely by rice variety, with losses of iron being higher than losses of zinc, which suggests that more zinc is deposited in the inner parts of the rice endosperm. Under the HarvestPlus project, improved rice germplasm will be provided to national partners in Bangladesh, Indonesia, Vietnam, India and the Philippines. The improved features will be incorporated into well-adapted and agronomically-preferred germplasm in ongoing breeding programmes at the national and regional level. A plant-biotechnology approach is the current priority for enhancing provitamin-A content of the rice endosperm. The leading varieties will be field tested for agronomic performance and compositional stability in at least four countries.

2.3.2 Wheat

The International Maize and Wheat Improvement Center (CIMMYT, Mexico) is leading the HarvestPlus research endeavour on wheat biofortification in order to increase people's intake of iron and zinc. Given that spring wheat varieties developed by CIMMYT and its partners are used in 80 per cent of the global spring wheat area, the potential impact of iron-enhanced wheat could be dramatic. The initial target countries will be Pakistan and India, in the area around the Indo-Gangetic plains, a region with high population densities and high micronutrient malnutrition. The highest contents of iron and zinc in wheat grains are found in landraces of wild relatives of wheat such as *Triticum dicoccon* and *Aegilops tauschii*. Because these wild relatives of wheat cannot be crossed directly with modern wheat, researchers facilitated the cross between a high-micronutrient wild relative, *Aegilops tauschii*, and a high-micronutrient primitive wheat, *Triticum dicoccon*, to develop a variety of hexaploid wheat that can be crossed directly with current modern varieties of wheat and have 40 per cent to 50 per cent higher contents of iron and zinc in the grain than modern wheat. The first biofortified lines will be delivered to the target region by 2005, i.e. broadly-adapted, high-yielding, disease-resistant wheat lines. The first high-yielding lines with confirmed iron and zinc contents in the grain should be available for regional deployment by mid-2007.

Researchers will be exploring the introduction of the ferritin gene in wheat and will establish the feasibility of increasing the concentration of iron and zinc in the grain using advanced biotechnology approaches in addition to conventional plant breeding. Molecular markers for the iron and zinc genes that control concentration in the grain were being identified in order to facilitate their transfer. Scientists will also carry out studies on bioavailability to determine the extent to which iron and zinc status in animal and human subjects is improved when biofortified varieties are consumed on a daily basis over several months.

2.3.3 Maize

Maize is the preferred staple food of more than 1.2 billion consumers in sub-Saharan Africa and Latin America. Over 50 million people in these regions were vitamin A-deficient in 2004. The International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA, Ibadan, Nigeria) are identifying micronutrient-rich maize varieties and will carry out adaptive breeding for local conditions in partnership with National Agricultural Research Systems (NARS) in Africa and Latin America. The project under HarvestPlus is initially focusing on maize varieties having increased contents of provitamin A because a useful range of genetic variation has already been identified for this trait. The first target countries are Brazil, Guatemala, Ethiopia, Ghana and Zambia.

To support the breeding programme, research is being conducted in Brazil, the USA and Europe to develop simple, inexpensive and rapid screening protocols for provitamin A, so as to reduce the cost of assays from \$70-100 to \$5-10

per sample. Research in Brazil and the USA is also focused on finding genetic markers to facilitate marker-assisted selection for provitamin A concentration. In collaboration with the University of Wageningen, a human efficacy trial was planned with provitamin A-rich maize in Nigeria for 2005 in order to study provitamin A retention or loss for different storage, processing and common cooking methods.

To facilitate extension and dissemination of biofortified maize varieties, country teams will be formed in the target countries in order to conduct adaptive breeding research, farmer-participatory variety evaluations, nutritional advocacy and promotional activities.

2.3.4 Beans

Common beans (*Phaseolus vulgaris*) are the world's most important food legume, far more so than chickpeas, faba beans, lentils and cowpeas. For more than 300 million people, an inexpensive bowl of beans is the main meal of their daily diet. The focus of HarvestPlus research is on increasing the concentration of iron and zinc in agronomically superior varieties.

Over 2,000 accessions from the International Center for Tropical Agriculture (CIAT, Cali, Colombia) gene-bank and several hundred collections of African landraces have been screened for their nutrient contents. While the average iron concentration in these varieties is about 55 mg per kg, researchers have found varieties the content of which exceeds 100 mg per kg. The eventual goals are to obtain favourable combinations for productivity and nutritional traits, double the iron concentration and increase zinc concentration by about 40 per cent. The first bred lines with 70 per cent higher iron will likely emerge in 2006, while lines with double concentration of iron are anticipated in 2008.

The proportion of iron and zinc that can be absorbed from legumes such as common beans is typically low, due to anti-nutrients, specifically phytates and polyphenols, which normally bind to the iron and zinc, making them unavailable to the organism. Research indicated that it might be possible to reduce polyphenol concentrations genetically, thereby improving iron bioavailability. In contrast, vitamin C is an iron-absorption enhancer because it binds to iron and prevents it from becoming attached to the iron-absorption inhibitors. Beans are often consumed with vegetables, including bean leaves with the potential of bean leaves as a source of vitamin C still to be explored.

2.3.5 Cassava

Cassava, also known as manioc or tapioca, is a perennial crop native of tropical America that is also widely consumed in sub-Saharan Africa and parts of Asia. With its productivity on marginal soils, ability to withstand disease, drought and pests, flexible harvest dates, cassava is a remarkably adapted crop consumed by people in areas where drought, poverty and malnutrition are often prevalent. Cassava is typically white in colour and, depending on the amounts of cyanogenic compounds, can be sweet or bitter.

The International Center for Tropical Agriculture (CIAT) will coordinate HarvestPlus' overall activities on cassava biofortification and be primarily responsible for research in Asia, Latin America and the Caribbean. The IITA will be responsible for cassava biofortification in Africa.

In collaboration with the University of Campinas, São Paulo State, Brazil, the total content of provitamin A in cassava varieties (roots) will be determined spectrophotometrically. Provitamin-A retention studies will also be carried out on different preparation and cooking methods used in cassava-consuming countries. A method for storing cassava roots for several weeks or a few months is needed for programmes quantifying hundreds of samples per year. Initial data suggest that the anti-oxidant property of a few yellow pigments in cassava roots may delay physical deterioration of the roots. The longer shelf life of yellow cassava roots may not only appeal to farmers and consumers, but may also increase the demand for biofortified varieties.

Nutritionally improved germplasm coupled with superior agronomic performance can be developed as a medium-term approach with products reaching the farmers as soon as 2009. The aim is to identify and select, from the varieties having both high provitamin-A contents and good agronomic performance, those with the highest iron and/or zinc content.

2.3.6 Sweet potato

Sweet potato is an important part of the diet in East and Central Africa where vitamin-A deficiency is widespread. At present, African predominant sweet potato cultivars are white or yellow-fleshed varieties that contain small amounts of provitamin A. In contrast, the orange-fleshed varieties are believed to be one of the least expensive, rich, year-round sources of provitamin A. Boiled orange-fleshed sweet potato, such as the Resisto variety developed in South Africa, contains between 1,170 and 1,620 Retinol Activity Equivalents (RAE) per 100 g and is estimated to provide between 25 per cent and 35 per cent of the recommended daily allowance for a preschool child. Experts at the International Potato Center (CIP, Lima, Peru), who developed a biofortified orange-fleshed sweet potato, estimated that when fully disseminated, this sweet potato could reduce vitamin-A deficiency in as many as 50 million children.

To encourage a switch from non-orange to orange-fleshed varieties, the texture of the latter must be changed because they tend to have a high-moisture content and adults prefer varieties with a low water content, i.e. a high dry biomass. Plant breeding is ongoing to increase the dry biomass of the provitamin A-rich orange varieties, to improve organoleptic characteristics and at the same time improve their resistance to viruses and drought.

About 40 varieties of sweet potato with high dry biomass and provitamin-A content have been introduced to sub-Saharan Africa. Of these, 10 to 15 were being tested widely in different agro-ecological areas in some countries. Some original varieties, mainly local landraces, have been well accepted by farmers and were being distributed on a small scale.

HarvestPlus' biofortification activities in sweet potato will be initially focused on Ethiopia, Ghana, Kenya, Mozambique, Rwanda, South Africa, Tanzania and Uganda. The variation in provitamin-A content of newly harvested roots can be as much as 45 per cent. Much of the provitamin A appears to be retained during storage, food preparation and cooking. In the South African Resisto variety, the provitamin-A activity of the boiled roots was between 70 per cent and 80 per cent of that of freshly harvested roots. Additional studies were to be carried out in 2004 to determine the provitamin-A losses during food processing and cooking based on the usual practices found in East and Central Africa. A human bioefficacy study using an organoleptically acceptable promising variety was planned for 2005, once the food processing studies were completed.

The \$100-million ten-year HarvestPlus programme will be financed during the first four years mainly by the World Bank, the USAID and DANIDA. The Bill and Melinda Gates Foundation would contribute \$25 million toward the total cost of the programme. In addition, the Canadian Agency for International Development (CIDA) will allocate funds for the Latin American part of the programme.

2.4 Regulatory issues and communication policies

Innovation in healthy foodstuffs is also fraught with costly failures. For instance, Procter & Gamble spent 30 days developing Olestra, a fat which the digestive system cannot absorb. But the product has been dogged by claims that it inhibits the absorption of vitamins and nutrients that may help prevent cancer; by a hostile lobby group, the Centre for Science in the Public Interest; and by regulatory problems. In 1996, after eight years of tests, the US Food and Drug Administration (FDA) allowed it to be used as an ingredient, but products made with it had to carry the warning that it might cause gastro-intestinal distress. In the summer of 2003, the FDA allowed the warning to be taken off advertisements (*The Economist*, 2003).

Moves toward healthier products and functional foodstuffs also fuel the professional lives of lawyers, regulators and stock-market analysts. Many companies have recently appointed advisory boards composed of top nutritionists. The FDA itself is acquiescing to companies' proposals to include in their products' health benefits in their labels. The FDA has, in fact, liberalized the rules on making health claims, adopting a four-tier system enabling consumers to decide based on how solid the science is behind any particular product's health claim. Calcium ability to protect against osteoporosis, for instance, is reckoned very solid while omega-3 fatty acids to prevent heart diseases are considered good, but second level. By early 2003, the FDA announced that from 2006 consumers must be informed of the amounts of trans-fats in foods notwithstanding the already wide publicity on the adverse effects of trans fats (*The Economist*, 2003).

Health authorities in Europe are also striving to regulate this kind of research and to establish marketing standards. All the difficulties relate to the need to demonstrate the impact of these foodstuffs on disease prevention in

humans. Does this mean we have to wait for sixty years of clinical studies in order to obtain such evidence? Under the programme FUF0SE, Functional Food Science in Europe, priority is given to the determination of 'markers' (or tools) which will scientifically enable the recognition of long-term benefits of functional foodstuffs. Those nutraceuticals which will show a beneficial impact will receive an authorization for marketing, rather similar to that given to medicines (European Commission, 2002).

Genetic engineering is useful for producing crops or food ingredients deprived of some undesirable elements or enriched with healthy substances, and therefore qualified as nutraceuticals. To be attractive to the consumers, these foodstuffs should not be too expensive. Ageing populations are a particular target for nutraceuticals, which can play a key role in the nutrition of old people suffering from under- and malnutrition. Between 1998 and 2002, it was estimated that the annual turnover of modified milks increased by 10 per cent in Europe and 36 per cent in the USA among people of more than 65 years.

Agri-food companies are also designing communication policies not just for consumers but also for physicians, pediatricians and nutritionists, like the pharmaceutical groups, in order to highlight the benefits of their products. These policies have to take into account the cultural differences with regard to food and nutrition among the countries. They should also state the preventive role of nutraceuticals as well as their therapeutic effects. For example, information available to consumers regarding the LC1 yoghurt, which states that it contains bacteria that foster a balanced intestinal flora, has, according to Nestlé, a more scientific slant in Germany, where one can talk of micro-organisms, while this approach would not be culturally accepted in France. This hints of cultural considerations in information about health products because despite the worldwide movement of people and international tourism, in countries of Anglo-Saxon culture food is generally considered as functional, i.e. one eats because he has to, while in the countries of Latin culture food must also give pleasure and should be surrounded with conviviality. Henceforth the need for communication policies to take account of this kind of nuances and that should be adapted to their targets.

3 Probiotics and Prebiotics

Probiotics are microbial food ingredients that beneficially influence human health while prebiotics are non-digestible carbohydrates such as fructo- and galacto-oligosaccharides. Probiotics have been used historically in different cultures in the form of fermented dairy foods, vegetables and cereals. Health effects of probiotics have been reported in the oral cavity, stomach, small and large intestine and the vagina. Although they consist mainly of lactic acid bacteria, bifidobacteria and yeasts have also been successfully used. Prebiotics are organic food components that exert health-promoting effects by improving the characteristics of intestinal flora. Established effects of prebiotics are dietary fibre-like effects such as anti-constipation, faecal bulking and pH reduction. The potential effects of prebiotics are similar to those of probiotics, since a major mechanism for prebiotics lies in the support of probiotics. The synergistic combination of both probiotics and prebiotics is called symbiotics.

At the Institute for Genomic Research (TIGR) in Rockville, Maryland, Karen Nelson and her colleagues at Stanford University are working to sequence the DNA of every bacterium found in the human gut. Previous estimates had put the number of bacterial species in the gut at about 500. Preliminary results from the guts of five healthy individuals have so far revealed about 1,300 species per person. As intestinal diseases could lead to subtle, long-term changes in gut bacteria, and changes in bacteria populations seemed to precede other diseases such as colon cancer, the TIGR team planned to compare healthy guts with those of people with Crohn's disease – an inflammation of the gut with no well-understood cause. On the other hand, sequencing the DNA of gut bacteria may lead to our being able to manipulate our intestinal flora in more sophisticated ways. The TIGR researchers also planned to study the microflora of other parts of the human body, such as the mouth, skin and genitals, that each harbours its own distinctive community microbes (Whitfield, 2004).

Under the European Commission, the cluster Proeuhealth brought together 64 research partners from 16 countries working in the fields of food, gastro-intestinal-tract functionality and human health. The cluster aimed to provide:

- a clearer understanding of the relationship between food, intestinal bacteria, and human health and disease;
- new molecular research tools for studying the composition and activity of the intestinal microbiota;
- new therapeutic and prophylactic treatments for intestinal infections, chronic intestinal diseases and for healthy ageing;
- a molecular understanding of immune modulation by probiotic bacteria and examination of probiotics as vaccine-delivery vehicles;
- process formulation technologies for enhanced probiotic stability and functionality; and
- commercial opportunities for the food and pharmaceutical industries.

Probiotic lactobacilli are known to affect immunomodulation. The increased understanding of the molecular factors affecting immunomodulation and immunogenicity will allow the selection of probiotic strains, with enhanced protective or therapeutic effects. European researchers have targeted two types of intestinal diseases: inflammations such as inflammatory bowel disease and infections such as those caused by rotaviruses and *Helicobacter pylori* (associated with ulcers) [European Commission, 2002].

Two specially-selected probiotics will be tested in long-term human clinical trials for their alleviating effects on inflammatory diseases, such as Crohn's disease and ulcerative colitis – immune-mediated diseases that result in chronic relapsing inflammation of the gut.

Delivering the health benefits of probiotics and prebiotics to consumers depends essentially on their successful processing. Viability, stability and functionality of these ingredients must be maintained during processing, formulation and storage. The effects of processing probiotics are being explored by the European researchers and used to develop optimal process and formulation technologies. New processing techniques will be applied to the development of functionally enhanced prebiotics and symbiotic combinations (European Commission, 2002).

4 Nutri-geno-proteo-metabolo-mics era of nutritional studies

Before the biotech era, research on food and nutrition dealt with establishing the importance of carbohydrates, fats and proteins in our diet, and with identifying trace elements and vitamins that are essential for the enzymes mediating our metabolism, respectively (Juurlink, 2003). The biotech era we are now just entering, concerns the understanding of the effects on specific gene expression of certain compounds we eat.

A good example is that of the regulation of a diverse group of genes whose proteins, generally enzymes, tend to either directly or indirectly scavenge strong oxidants or to decrease the probability of production of strong oxidants; these proteins are referred to as phase-2 proteins and, since most of them are enzymes, they are commonly referred to as phase-2 enzymes (Juurlink, 2003).

Strong oxidants can damage DNA thereby resulting in mutations that may lead to cancer; they scavenge the endothelial-derived vascular relaxation factor nitric oxide thereby promoting hypertension; and they also activate kinase pathways that lead to inflammation. The phase-2 terminology comes from the terminology describing enzymes that metabolize xenobiotics: phase-1 enzymes being the mono-oxygenases, mostly cytochrome P450s, that convert the generally hydrophobic xenobiotics to strong electrophiles, while the phase-2 enzymes form water-soluble adducts by the addition of glutathiol, glucuronosyl or sulphate groups. Since the phase-2 enzyme genes all have anti-oxidant response elements (AREs) in their promoter regions, any gene with an ARE in the promoter region is referred to as phase-2 protein (enzyme) (Juurlink, 2003).

Phase-2 enzymes include the classical ones such as NAD(P)H: quinone oxidoreductase 1, glutathione S-transferases A, M and P families, UDP-glucuronosyl transferases, as well as the more recently defined phase-2 proteins: ferritin H and L chains; cystine/glutamate antiporter, peroxiredoxin I, heme oxygenase 1; L-gamma-glutamyl-L-cysteine ligase, metallothioneins, etc. All these proteins directly or indirectly inhibit strong oxidant formation, e.g. ferritin through sequestering iron, or promote strong oxidant scavenging, e.g. NAD(P)H: quinone oxidoreductase. Phase-2 protein genes are coordinately upregulated through activation of an ARE in their promoter regions. Phase-2 protein inducers can be found in our diet: kaempferol, a flavonoid present in high amounts in kale; a flavonoid fraction found in blueberries/cranberries; enterolactone, a metabolite of the principle lignan secoisolariciresinol diglucoside found in the flax seeds; ellagic acid found in strawberries and raspberries/blackberries; the flavolignan silibinin obtained from milk thistle (*Silybum marianum*) fruit; sulforaphane, the isothiocyanate metabolite of the glucosinolate glucoraphanin (Juurlink, 2003).

There is much evidence that dietary intake of such phase-2 protein inducers can increase phase-2 gene expression in a number of tissues and that such induction can decrease the incidence of chemically induced tumours. At the Plant Biotechnology Institute (PBI, National Research Council of Canada, Saskatoon, Saskatchewan), Juurlink and colleagues

are working on the phase-2 protein-inducing isothiocyanate derivatives of certain glucosinolates, 4-methylsulfinylbutyl glucosinolate, commonly known as glucoraphanin. The Canadian researchers have shown that dietary intake of glucosinolates that give rise to phase-2 protein-inducing isothiocyanates can improve hypertension in the spontaneously hypertensive stroke-prone rats (SHRsp); in addition, oxidative stress and inflammatory changes in various tissues in the ageing SHRsp was down-regulated (Juurlink, 2003).

The NRC-PBI's researchers also examined the effects of administration of the flavonoid quercetin in a neurotrauma model. They found that quercetin administration after spinal cord injury promotes retention of function, correlated with decreased inflammation. Not only is quercetin a very selective kinase inhibitor, but it is also known to be a phase-2 protein inducer (although more than an order of magnitude higher concentration of quercetin is required for this activity than is the case for sulforaphane) (Juurlink, 2003).

In collaboration with Shawn Ritchie and Dayan Goodenowe, Juurlink has begun examination of the effect of broccoli sprouts containing glucosinolates that are converted into phase-2 protein gene-inducing isothiocyanates on the metabolic profile and they have seen pronounced effects in liver and other organs (Juurlink, 2003).

In summary, we are entering an era in nutrition where we are beginning to understand how phytochemicals influence metabolism and gene expression. Since many phytochemicals can have multiple actions such as activating signal transduction pathways that directly or indirectly alter gene expression or influence protein function that result in adverse metabolic reactions, one must use multiple approaches to understand how phytochemicals either individually or in combination affect us. Henceforth, a combined metabolomic/proteomic/genomic approach is required (Juurlink, 2003).

5 Modification of food tastes and healthier food production

A breakthrough in the food industry would be to offer healthier versions of popular foodstuffs without affecting the taste. If it succeeds to do so, grapefruit juice could be sweet without added sugar and potato chips flavourful with half the current content of salt. This kind of research could have applications in medicine manufacture. In April 2003, Linguagen Corp., a biotechnology company in Cranbury, New Jersey, conducting taste research, was granted a patent for the first molecule that will block bitter tastes in food, beverages and pharmaceuticals. The compound, adenosine 5'-monophosphate or AMP, occurs naturally (in human breast milk, among other sources) and, when added to certain foodstuffs, including coffee and canned or bottled citrus juice, the company states, it blocks some of the acidic tastes from being felt by the tongue (Day, 2003).

The finding of a bitter suppressor attracts all food companies, e.g. Coca-Cola Co., Kraft Foods and Solae, a soya-foods firm owned by E.I. Dupont de Nemours and Co., Inc., and Bunge have each expressed interest in flavour and taste biotechnology. Kraft Foods and Solae are Linguagen clients while Coca-Cola Co. has signed a research deal with Senomyx, another biotechnology company (Day, 2003).

Some research has focused on finding compounds that would trick the receptors on the tongue by accentuating or blocking certain elements in the food, allowing people to taste a cup of coffee without adding cream or sugar, or the sensation of full fat in low-fat products. Processed foods such as canned soups, sauces and snacks like potato chips contain high amounts of salt to mask the bitter tastes that result from the very hot cooking process. Soft drinks are sweetened to tone down the bitter taste of caffeine. Food and beverage companies are, on the other hand, very concerned, as a group, about health and nutrition because of all the reports on epidemic obesity, epidemic diabetes, cardio-vascular diseases and hypertension. Hence the search for compounds that keep food tasty, minus salt, sugar and fat (Day, 2003).

So far scientists at Linguagen Corp. have discovered about 20 compounds that blocked bitter tastes and have been granted patents to use four of the compounds as bitter blockers. Because humans have more than 30 separate bitter taste receptors, finding a universal bitter blocker is nearly impossible. Linguagen Corp. is also trying to discover and market a natural sweetener to replace artificial ones like aspartame or saccharine, which often leave a bitter after-taste. The company planned to license bitter blockers to food, beverage and medicine manufacturers in the USA by early 2004 (Day, 2003).

Senomyx, based in La Jolla, California, is also developing bitter blockers, as well as molecules that block unpleasant smells and others that increase the salty taste in low sodium snacks while decreasing the product salt content. The research was in the early stages by mid-2003. The Coca-Cola Co. – the world's first-biggest soft-drink company, commercializing 400 beverage brands in 200 countries, with an annual turnover of \$21.044 billion and a net profit

of \$4.347 billion in 2003 – is one of the company's clients. PepsiCo, Inc., is also interested in taste biotechnology and in anything that can impact food or beverages on a large scale.

Since AMP is not bioengineered and regarded as safe, it will be accepted by people and not shunned by consumers like previous additives which were supposed to revolutionize low-fat foodstuffs but later performed far below expectations. Much of current taste research is the result of radical rethinking of the mechanisms of perception of tastes by humans that has taken place since 1993. Researchers have shown that the human brain had the ability to recognize a variety of flavours including bitter, sour, savory and sweet all over the tongue rather than in specific areas of the tongue, as it was thought before. The tongue papillae contain the taste buds; when food mixes with saliva, molecules dissolve on the papillae and, through the taste buds, send a signal to the brain, which interprets the flavour of what is being eaten. When a bitter blocker hits the tongue, it prevents the bitter taste receptors from being activated. The brain is thus unable to recognize the bitter flavour, while the latter is still embedded in the food or beverage (Day, 2003).

6 Correlation of genetic markers with beverage and food quality

6.1 Correlation of genetic markers with meat quality

In 2002, the Maryland (Savage)-based biotechnology company, MetaMorphix, acquired the livestock genotyping business of Celera Genomics, a company founded in 1998 to sequence the human genome; it then joined up with Cargill, Inc., to commercialize a genetic test that will help to reveal, prior to slaughter, a cow's propensity to produce desirable meat. That task is being carried out by analyzing thousands of so-called single-nucleotide polymorphisms (SNPs) in the bovine genome. A SNP is a place where the genomes of individual animals vary by a single nucleotide. SNPs are therefore convenient marker versions of particular genes, and different versions of genes result in differences between animals (*The Economist*, 2004b).

MetaMorphix and Cargill, Inc, tried to find out which SNPs were associated with variations in meat quality, such as flesh colour, amount of marbling, wetness and tenderness, so that these could be identified before slaughtering an animal, and suitable animals will thus be reserved for breeding. In 2002-2003, Cargill, Inc., studied 4,000 cattle, trying to correlate MetaMorphix's genetic markers with meat quality – and with other important traits, such as growth rate. Almost 100 useful SNPs have been identified from this study. As a result, a prototype testing kit was to be used by the firm as of August 2004. The first 'designer meat' produced this way was expected to be marketed in 2005 (*The Economist*, 2004b).

6.2 Genetic tagging of aquacultural species

Species-specific DNA markers can be used to identify animal species such as commercial molluscs and crustaceans, which represent a high proportion of aquacultural species. For instance, in Thailand, at the National Center for Genetic Engineering and Biotechnology (BIOTEC) Marine Biotechnology Unit, species-specific markers based on 16S ribosomal DNA (rDNA) polymorphism have been developed for penaeid shrimps, tropical abalone and oysters.

The black tiger shrimp (*Penaeus monodon*) is the most commercially important cultured species in Thailand. Because of outbreaks of diseases, the white shrimp (*P. vannamei*) has been introduced into Thailand and cultured commercially. On the other hand, external characteristics of *P. monodon* and *P. semisulcatus* are similar, but the growth rate of the latter is approximately three times slower than that of the former. In addition, *P. merguensis* larvae, which could not yet be successfully cultured, were sold as those of *P. vannamei*. Species-specific markers were therefore developed for identifying the afore-mentioned species and *P. japonicus* as well. These markers can be applied to ensure quality control by properly labeling traded shrimp larvae.

Three species of tropical abalone are found in Thailand's waters: *Haliotis asinina*, *H. ovina* and *H. varia*. However, *H. asinina* is the most productive one, as it provides the highest ratio (85 per cent) between meat weight and total weight. *H. asinina* specific markers based on 16S rDNA polymorphism have been developed in order to prevent

supplying the wrong abalone larvae for the industry as well as to foster quality control of abalone products from Thailand.

Oyster farming has shown rapid growth in Thailand over the last few years. Taxonomic difficulties relating to Thai oysters have had a limiting effect on the culture efficiency and development of their closed life cycle. Molecular genetic markers have therefore been developed to identify the three commercially cultured oysters, *Crassostrea belcheri*, *C. iredalei* and *Saccostrea cucullata*.

6.3 DNA fingerprinting of grapevine varieties

Since 1990, US and French researchers have been trying to establish the phylogenetic tree of the varieties of grapevine grown throughout the world, using the fingerprinting technique. The research consists of analyzing the structure of certain regions of the genome of some grapevine varieties and comparing it with that of other varieties, so as to establish possible phylogenetic relations. For this analysis, the DNA is extracted from young ground leaves, but also from fruits and branches. The results of this first research have been published in 1999 in the *Science* journal (Nau, 1999a).

There are about 6,000 grapevine varieties cultivated worldwide. In order to establish the origin of a variety, specialists used to rely on phenotypic traits, such as the morphology of leaves, berries and grapes. In this way, varieties could be grouped in a few families. DNA fingerprinting enables the researchers to go further. It appears that the current grapevine varieties are the remote offspring of the grapevines grown during the Antiquity around the Mediterranean, or during the European Middle Ages. The current varieties are the result of lengthy breeding activities, identification and comparison work, and stabilization of the selected strains or lines (Nau, 1999a).

The team led by C. Meredith and J. Bowers of the Department of Viticulture and Oenology of the University of California, Davis, has confirmed that the cabernet sauvignon variety – which is dominant in the Medoc region of France and is at the origin of most red grapevine varieties in the New World – was in fact the offspring of the cabernet franc and sauvignon, two varieties deeply entrenched in the middle valley of the Loire river. The cooperation between the Californian team and the French specialists of the National Higher School of Agronomy, Montpellier, associated with the Genetic Research and Breeding Unit of the National Agricultural Research Institute (INRA), has led to undisputable results concerning the origins of various grapevine varieties: the chardonnay (the most famous and expressive variety in Burgundy), aligote (also from Burgundy), gamay (red variety) and melon of Burgundy (which has colonized the area of muscadet) are all cousins and almost siblings. Such a conclusion, derived from the analysis of DNA fingerprinting, was not a surprise for oenologists and tasters because the wines made from these four varieties share common structures and aromas. This kinship is particularly expressed in the ageing wines.

Similarly, aged wines of the chenin variety resemble the Hungarian tokay (Nau, 1999a).

But more surprising than the discovery of that kinship among the four grapevine varieties, was the identity of one of the progenitors of the initial couple that gave rise to these varieties. Indeed, several historical elements were in favour of the creation of lines through the cross pollination between the pinot noir and the white gouais; these crosses have given birth – as proven by the fingerprinting analysis – to the three white and red varieties grown for a long time in various French provinces, and for some decades, in many regions of the globe. The surprising aspect of this discovery was that the white gouais is almost unknown, although the vine specialists in Montpellier continue to grow it and to make wine from it for their own pleasure. However, this variety has played a key role in the origin of French viticulture, according to R. Dion in his *Histoire de la vigne et du vin en France des origines au XIXe siècle* (History of vine and wine in France from its origins to the 19th century). A document dated from the 12th century mentioned this variety as a lower-grade one; in 1338, the white gouais was found in Metz under the name of goez; at that time, instructions were given to eliminate this variety from all the Metz territory and to privilege only the white and black fromental, considered as higher-grade varieties. The gouais was found in Paris during the 14th century and, owing to the expansion of the workers' population, it progressively replaced the pinot noir of Burgundy, which was a good variety of Parisian vineyards. The extension of the gouais was due to the wish of the winemakers to produce a cheaper wine. However, the phenomenon was limited to Paris and its suburbs; in the vineyards located away from the capital, the gouais was rejected, more noble grapevine varieties were used and contributed to the reputation of French viticulture (Nau, 1999a).

The white gouais was also formerly grown in the Jura and Franche-Comté. For the US and French researchers, this variety which has played a key role in the history of vine and wine, is the same as the heunisch variety of Central Europe, introduced in Gaul by a Roman emperor originating from Dalmatia. In Montpellier, the French researchers participating in the joint study with the US scientists from the University of California, Davis, have tried to reproduce the breeding between the pinot noir and white gouais in order to seek confirmation of the genetic research. Other attempts were expected to widen even more the range of cultivated grapevine varieties, for both their fruits and wines derived from them. But this approach was hindered by a drastic regulation, which practically prohibits any venture of this kind, while non-French winemakers and vinegrowers could do it (Nau, 1999a).

In Apulia, in the heel of the Italian boot, drawing on grapes grown by up to 1,600 small farmers in the area, a California wine consultant associated with another Italian wine consultant from Friuli (northeastern corner of the country) are producing and marketing wines that have scored a great success worldwide, with 2004 projected sales 15 times as big as those in 1998, the winery's first year. The wines are called A-Mano – handmade – and by far the best known

is a robust red made from a once-obscure grape named primitivo (Apple, 2004).

DNA testing by Carole Meredith at the University of California, Davis, established that primitivo is a descendant of a grape called crljenak kastelanski, widely known in the 18th and 19th centuries on the Dalmatian coast of Croatia (a crljenak cross with dobrinic, plavac, mali, is being grown on that area today). California's zinfandel, she showed, is genetically the same as primitivo, though how it crossed the ocean remains a subject of dispute (Apple, 2004).

Apulian primitivo and zin are not twins, of course; climate, soil and vinification all help to shape a wine's look, aroma and flavour, along with the grape variety. But the two share several characteristics: both are fruit-rich, chewy, sometimes lush wines, a deep violet-red in colour, often too high in alcoholic content for comfort, but much more subtle if carefully handled (Apple, 2004).

For years, primitivo was used to add unacknowledged heft to chianti, barbaresco and even red burgundy. Nowadays, primitivo can stand on its own feet. In addition to A-Mano primitivo, other high-quality primitivos are grouped in an organization called the Academia dei Racemi, not a true cooperative but an association in which each member makes his own wine and joins the others for marketing support and technical advice. Based in Manduria, between the old cities of Taranto and Lecce, the group includes value-for-money labels like Masseria Pepe, Pervini and Fellingine (Apple, 2004).

7 Food safety

It is an established fact that, despite current misgivings about food safety and unhealthy foodstuffs, what we eat and drink is nowadays subjected to more safety and quality controls than ever, and the effectiveness of these tests is demonstrated by the choices we regularly make. In Spain, for instance, according to the 2003 Consumer Barometer released by the Eroski Group Foundation, the public has a degree of confidence in its food of 7.29 points out of 10. Furthermore, a survey by the Federation of Food and Drink Industries (FIAB) showed that 81.3 per cent of Spaniards interviewed considered the foodstuffs they bought as safe (Sánchez Bardón, 2004).

However, according to a recent survey carried out by the Spanish Society for Basic and Applied Nutrition (AESA), 32 per cent of Spaniards had unsuitable daily eating habits and 64 per cent needed to improve their diet. By late 2002, the Spanish Agency for Food Safety had been created and its main task was to coordinate the implantation of effective control systems, with alert mechanisms to detect possible failures in the food-safety chain and manage them without repercussions on public health. The AESA is also acting as a watchtower for emerging risks and is responsible in Spain for handling alerts originated elsewhere. During the agency's first year of existence, 633 food bulletins have been issued, 126 of which were alerts involving such administrative decisions as the withdrawal of certain batches of food. The AESA's president stated that 'we have to make sure that the consumer's perception of risk corresponds to the risk there actually is. Fear has no bounds, but information combats it on every front' (Sánchez Bardón, 2004).

There were over 27,907 food industries registered in Spain, and the number of authorized abattoirs reached 800 in 2004. The food and drink industry turned over more than €600 billion a year, and the agricultural and food sector was the third-biggest employer in the European Union in 2003. Protective controls have to match up to this (Sánchez Bardón, 2004). See also Schmidt and Rodrick (2003).

8 Organic or biological agriculture

8.1 Definition and trends

The phrase “organic or biological agriculture” designates an agricultural mode of production that does not rely on the use of chemicals, e.g. fertilizers and chemical pesticides. It also excludes any genetically modified organism, and is labour intensive. It does not mean that the products are necessarily of a higher quality than those derived from conventional agriculture.

How much acreage is dedicated to this version of farming? It depends on the definition, but according to an extensive survey by the Germany-based Ecology and Agriculture Foundation, in 2003 Australia led with 7.6 million hectares, followed by Argentina (3 million ha) and Italy (1 million ha). When expressed as a percentage of total arable land, these figures are far from stunning. The highest proportions are found in Europe where organic agriculture methods are well defined and products registered. Thus Austria, the leading European country in biological agriculture and products, devotes 11.3 per cent of its total arable land to this kind of agriculture. In France, the proportion is only 1.4 per cent and 11,000 farmers are considered organic producers. It is Europe’s first-biggest agricultural country occupying 13th place with regard to biological agriculture (Amalou and Dupont, 2004).

The methods of biological agriculture have been applied in France since the 1950s, but it was only at the end of the 1970s that small groups of farmers began to organize themselves, e.g. to create the National Federation of Biological Agriculture (FNAB). In October 1979, the first adviser in biological agriculture had been officially hired by an agriculture chamber, that of the Yonne Department, but the first farmers practising this type of agriculture were not taken seriously by their neighbours, or the institutions (Lorelle, 2000c).

During the summer of 1996, the ‘mad-cow’ disease led to the harsh criticism of industrialized agriculture. The French minister of agriculture highlighted the importance of high quality food and ordered a report on biological agriculture. At the end of 1997, the French government approved a multi-annual plan in favour of this type of agriculture. The demand for its products was strong: in 1999, it grew by about 30 per cent, especially owing to the demand by the supermarkets, which showed a keen interest in the products. Despite government assistance provided since 1997 that aimed at facilitating the reconversion of farms, national production could not meet the market demand. In 1999, 8,140 farms were practising biological agriculture over 316,000 hectares, i.e. a threefold larger area than five years earlier, and this kind of cultivation concerned only 1 per cent of the whole useful acreage. To meet the demand, imports are growing, and it is forecast that in 2005, 1 million hectares should be devoted to biological agriculture in order to meet the demand. Specific training is being provided and financial assistance is given to those farmers who decide to carry out a reconversion to biological agriculture (Lorelle, 2000c)

In the United Kingdom, demand for organic food is growing at over 40 per cent a year. This demand amounted to nearly

\$1.6 billion in 1999, with a third of the population buying organic food (Bate, 2000). In France in 2002, 65 per cent of French people had consumed a ‘bio’ product during the last 12 months, compared with 50 per cent in 2001 and 40 per cent in 2000 (Dupont, 2002).

In 2003, however, the French market of organic foodstuffs and products, labelled as “bio”, after growing at a 20 per cent annual rate, showed signs of slowing down. Although those responsible for producing and transforming organic products tended to underestimate this stagnation (particularly in the aftermath of the food crises that struck Europe), the growth rate of the ‘bio’ products market was estimated at 6 per cent to 10 per cent in 2003. According to the institute TNS Media Intelligence which scrutinizes the evolution of consumers’ behaviour, 57 per cent of French housekeepers had bought at last one ‘bio’ product in 2003 – a low figure compared with the levels of consumption in the United Kingdom (80 per cent), Italy and Germany (Dupont, 2002; Amalou and Dupont, 2004).

There are several reasons for this stagnation. In the case of milk, the price of the litre has fallen by 0.02 to 0.08 cents since early 2002. Meat profits were 20 per cent to 30 per cent less. Producers of poultry, vegetables and fruits suffered from crises comparable to those affecting their colleagues in conventional agriculture. However, there did not seem to be an overproduction, because although consumption of ‘bio’ products was decreasing, it was not met by French production. In 2002, ironically, 21 million litres of milk produced in France were ‘declassified’ and sold through conventional outlets, while ‘bio’ products sold in France were imported, e.g. fruits, vegetables, cereals and exotic products (Dupont, 2002).

Most of stakeholders involved in organic farming and production, as well as analysts, agree that the crisis is rather a marketing issue; in other words, ‘bio’-product producers did not have the full capacity to put these products in the conditions when the consumers want to find them. The French group Biolait that collects one-fourth of ‘bio’ milk produced in France failed to impose its prices to the transformers who went away; henceforth the declassification of this milk into conventional one, and the company Lactalis whose supply broke down, had to import its ‘bio’ milk from Germany (Dupont, 2002).

Meanwhile, there are also problems of distribution and price, as well as certification and fraud issues.

8.2 Distribution of organic or ‘bio’ products

Although hyper- and supermarkets are the first selling places of ‘bio’ products (52 per cent of purchases are made in these places), the French Carrefour supermarkets sell about 300 products, while the British Sainsbury plc offer a much wider range of 1,200 products. Specialized shops are also less than 1,000 in France. Consequently customers have some difficulties finding ‘bio’ products in their usual shopping places (Amalou and Dupont, 2004).

However, partnerships have been established between these retailers and the farmers. Some farmers are also

trying to diversify their outlets so as not to depend on the supermarkets only: thus, in France BioBourgogneViandes, created in 1994 near Dijon and comprising some forty cattle raisers, is selling meat to individual clients directly (for an 18-kg order, the client pays €12 per kilo and the transport cost). BioBourgogneViandes has also purchased a first butcher's shop in the central market of Dijon, while the number of members grew to 70 by the end of 1999, with an annual turnover of €2.4 million. The cattle raisers owned four shops in different villages and were selling, in addition to meat (by correspondence), such biological products as wine, cheese and vegetables. While in 1997, all the meat produced by BioBourgogneViandes was delivered to Auchan supermarkets, in 1999 only 40 per cent was bought by the latter and 60 per cent by individual customers through the associated butcheries and specialty shops. BioBourgogneViandes claimed it had created jobs in small villages and saved businesses (Lorelle, 2000c).

8.3 Pricing

The price of 'bio' products remains the principal obstacle to their purchase. According to their survey carried out in October 2003 by the review *60 millions de consommateurs* in France, 'bio' products sold in hyper- and supermarkets cost 40 per cent to 60 per cent more than conventional products, and 70 per cent to 100 per cent more in open-air markets and specialized shops. It is true that organic farming needs more labour, particularly for growing vegetables and fruits. Also the small volumes of milk and meat make the harvest, bottling and transportation of these products very costly, because one has to find the industrial tools (rather few) that meet the stringent standards of this form of production. Only 'bio' eggs, laid by hens raised in open backyards and fed with foodstuffs derived from organic farming, have met with great commercial success (it has been underlined by *60 millions de consommateurs* that this way of raising poultry did not affect the egg nutritional value or taste) [Dupont, 2002; Amalou and Dupont, 2004].

There is also the issue of economies of scale. The high costs of 'bio' products and the need to successfully compete with conventional products have led organic farmers in Europe to request assertive policies from the respective governments in favour of organic agriculture, starting with a marked increase in the acreage devoted to it. Germany, Italy, Denmark and Austria have designed public policies to support the growth of organic farming, while in France it has been suggested that the acreage devoted to organic farming should reach 3 per cent of total arable land, in order to become economically sound (Dupont, 2002).

8.4 Certification

Biological agriculture in the case of France, is submitted to drastic constraints as determined by their agriculture ministry. These are:

- culture rotation is strongly recommended in order to maintain soil fertility; animals should not be kept in narrow facilities (e.g. feedlots);

- breeds should be adapted to their environment and fed with products from biological agriculture, i.e. animal flours and GMOs are prohibited;
- besides vaccination, animals are treated with the help of 'soft' medicine. Chemical fertilizers, herbicides, insecticides, synthetic fungicides are also prohibited. They are replaced by organic fertilizers (manure), guano and marine algae, plant wastes and rock phosphate.
- weeding is manual, mechanical or thermal.
- pests are controlled through the use of nets, repellents and the release of natural predators. Only when a great threat to the crops exists, chemical pesticides are authorized.
- for those who practise both conventional and biological agriculture (half of them in France), the fields devoted to each type must be separated and accountability should be distinct; and
- two or three years are also needed for converting farmland to biological agriculture so as to eliminate chemical residues in the soils. Products sold during this period are considered conventional, but the French government has decided to provide financial assistance in order to compensate the gap in revenue (Hopquin, 2000a).

In other words, organic farmers defend an alternative agricultural, economic and social model. They prohibit the use of genetically modified organisms and demand, in case the ban on transgenic crops is actually lifted in Europe, a threshold of 0.1 per cent for an adventitious presence of GMOs in their crops, instead of 0.9 per cent as it has been decided for conventional crops.

The requirements for organic farming are applicable throughout Europe, with some national differences that may create distortions in competition. In France, the requirements for livestock husbandry are the most stringent, as all the feed should be produced on the farm itself.

The AB logo, which applies to 'bio' products in France, can be applied to non-French organic products provided that they meet the national requirements. A common European logo also exists to label those 'bio' products. These logos do certify the mode of production of the product, but not its quality as does the Red Label in France (Dupont, 2002).

Regarding exotic products, they can also be labelled with the same AB logo, but they raise problems of traceability and control. Many developing countries are devoting an increasing acreage of their arable land to organic farming, as they are attracted by premium prices on the international market. This is, for instance, the case of Chile, which has important outlets for its organic products in the European Union and Japan (where Chilean products have gone through the system of certification and received the 'bio' seal). Surinam and Papua New Guinea head the list of African, Caribbean and Pacific (ACP) countries as 'bio' producers. Demand in the Western countries for organic fruits and vegetables is enticing producers throughout the

ACP countries to be organized and establish their foothold in the market of opportunity. In early October 2001, more than 170 traders, producers, researchers and support agencies converged on Port-of-Spain, Trinidad and Tobago, to do that at a conference on diversifying regional exports through developing organic agriculture. They came from Cameroon, Malaysia, 17 Caribbean nations and departments, 11 countries of Central and South America, and eight countries of North America and Europe. The conference launched a new study on *World markets for organic fruit and vegetables* by the FAO, the International Trade Centre of the United Nations Conference on Trade and Development (UNCTAD) and World Trade Organization. Debates at the conference led to concrete proposals for national standards, regional certification, information services and special measures for smallholders wanting to switch to organic farming.

8.5 Certified denomination of origin

The certification of organic or 'bio' products is part of a wider trend that consists of drawing the consumers' attention to the origin and quality of their foodstuffs and beverages. This trend responds to the concern that quality is threatened by industrialization of food production and processing. Although reaching a high quality standard may require years of work and great financial endeavours, farmers are interested in following suit. In France, for instance, one-third of farmers, 6,700 companies and 6,000 distributors were, in 2001, engaged in official procedures aimed at certifying their products (Dupont, 2001). Certification in France deals with the quality and origin of the product. In addition to the AB label for 'bio' products, there is the AOC label (appellation d'origine contrôlée – certified denomination of origin) which dates back to 1935; it indicates the provenance of a product whose characteristics are associated with the natural environment and local knowledge. The Red Label, created in 1960, only indicates the higher quality of taste of the product, but not its provenance or mode of production; a transformed product with Red Label does not necessarily derive from a raw material of the same quality. Finally, a certificate of conformity guarantees, since 1988, the fulfilment of a series of requirements set up by a group of producers, processors or distributors; this private logo which entails a fee from the petitioner guarantees a constant quality of the product (Dupont, 2001).

Over the 1990s, there has been a proliferation of mentions and signs, official or private, that claim the quality, origin or tradition of a wide range of agri-food products. This has been interpreted as the counterweight to the increasing industrialization of agriculture: in a few decades, the proportion of processed agricultural products purchased by households rose to 80 per cent and even more. On the other hand, food crises caused by listeriosis, bovine spongiform encephalopathy (BSE or 'mad cow' disease), foot-and-mouth disease, the suspicion about the effect of heavy metals on health as well as about genetically-modified organisms (GMOs) have provoked an anxiety among consumers who demand the traceability of their foodstuffs. Farmers who have been submitted to the successive reforms of the common agricultural policy, wish to redefine their identity

and role; they consider therefore that being able to trace their products and guarantee their quality is an appropriate way to respond to consumers' expectations. With regard to supermarkets, they have created brands which refer to the positive image of well-known production areas and which are recognized by the demanding consumer as a guarantee of quality (Faujas, 2004).

To be granted an AOC, farmers must adopt a collective approach; they should create a union to defend the product, work together with the enquiry teams of the National Institute of Denomination of Origin (INAO) during three, four or even ten years, and make a lot of efforts and use their know-how. From 1997 to 2001, the number of farmers having adopted this approach increased by 14 per cent, while the total number of farmers decreased by 4 per cent. The approach is rewarding: for instance, the production of a kind of cheese called 'morbier', which was granted an AOC in 2000, doubled in two years and the number of its manufacturers rose from 25 to 40; the price of the AOC cheese is 30 per cent higher than that of ordinary cheese. It is also true that granting of an AOC label and the quality attached to it have an impact on the value of land: the annual price of land planted with olive trees in the region of Nyons (with an AOC label) increased 2 per cent more than that of non-AOC land. This enabled the farmers to resist the pressure exerted on land by tourism or urbanization (Faujas, 2004).

AOC productions cannot be transferred outside their site of production. The green lentil of Puy or the Roquefort cheese is considered collective property and thus, cannot be expatriated. This is a major difference with a brand an industrialist can keep while transferring its production to Asia or Africa to lower manufacturing costs (Faujas, 2004).

The trend toward quality and labelling has its limitations. Firstly, there is a risk of confusion among the consumers. The latter may be tempted to choose an imitation of AOC, less costly. It is the role of the INAO to monitor the market and make sure that the reputation of a product originating from a specific area is not undermined. It seems that in France the volume of AOC products on the market is close to what this market can absorb. For instance, AOC wines represent 55 per cent of total production; it is not considered unreasonable to raise this proportion and convert all the vineyards to that quality level. The same is true for poultry, a large part of which is being sold with a red label and an indication of origin (Faujas, 2004).

The number of farms selling some 600 AOC products with a protected geographic indication (IGP) was 140,000 out of a total of 650,000 on the French territory (2003). These farms include vineyards, vegetable growers, fruit and olive-tree growers and livestock husbandry. Their number could still rise – one farmer out of three could be involved in this kind of production in the medium term – but this approach could not be extended to the whole French agriculture (Faujas, 2004).

European certification includes a certified protected origin (AOP), the French AOC, as well as the protected geographic indication, which establishes a less strict geographical

relationship than the AOP (Dupont, 2001). In the United Kingdom, a leading company in the production of 'bio' products is Duchy Originals, founded by the Prince of Wales and established at the Home Farm of Tetbury, near the Prince's residence of Highgrove (Gloucestershire). It sells chocolates, bread, honey, biscuits, cheese, ham, sausages and soft drinks. On 23 March 2004, a new product has been launched: a 'bio' shampoo. The latter, bearing the logo Houmont, contains rose and lemon essences and will be a strong competitor of Body Shop's comparable products. It is a joint venture between the Prince of Wales and a famous London-based hairdresser. Duchy Originals is a prosperous enterprise, with a €22-million turnover in 2003-2004 and profit reaching €343,000. The 'Prince Charles' label is found in big department stores as well as worldwide, particularly in the USA and Commonwealth countries. Benefits are transferred to a charity foundation chaired by the Prince of Wales. Since its creation in 1990, about £2 million had been transferred to philanthropic associations by Duchy Originals which employed 100 people (Roche, 2004).

Official certifications are facing the competition of private certifications, such as the indication of local or regional brands, of provenance, emphatic mentions, which do not necessarily represent a qualitative content or value and which are not submitted to an independent review. Monitoring and control of 'bio' products are carried out in France by some thirty certifying bodies, except the AOCs which are under the control of the National Institute of Denomination of Origin. All these bodies are authorized by the state and their action is followed by that of the General Directorate for Competition, Consumption and Fraud Repression (Dupont, 2001).

The denomination of origin label (AOC) is not peculiar to rich countries. Thus, China, with the assistance of France, has adopted a law on appellations in 2000 and has created about 30 AOC labels concerning yellow wine, teas and hams that are typical for some regions. Vietnam has followed suit in 2001; the first geographic indication regarding the 'nuoc mam of Phu Quoc' has attracted the interest of Unilever which invested \$1 million for transferring its production in that island; since then, the price of this AOC nuoc mam has trebled. Sixteen countries of West Africa have requested the French INAO to identify two products in each of them that could be certified. Morocco wants to protect its argan oil (extracted from the seed of the tree *Argania spinosa*, an endemic species of the south-west of Morocco), while Bolivia wishes to label its wine and quiñoa – a nutritious seed from *Amaranthus quiñoa* – and Brazil wants to tag its best wines. These efforts demonstrate that the globalization of nutrition and food should not necessarily lead to homogenization of products but to the promotion of trade relations that respect nutritional differences and cultures (Faujas, 2004).

8.6 Segregation

In the fall of 1999, two French industrial corporations, Glon-Sanders – the leader in animal feed and egg production in France – and Bourgoin – the European leader in poultry production – decided to set up a non-genetically-modified

(GM) soybean chain, through which this legume was traced during the whole transformation process, from the seeds to the eggs and poultry sold to retailers. Eleven cooperatives, including 2,000 farmers and representing 12,000 hectares, responded positively to both industrialists in order to produce the so-called 'soja du pays' (genuine local soybeans). In 1999, the expected harvest was 50,000 tons of beans (i.e. 20 per cent of French production) and in 2000 more than 100,000 tons. The soybean meal (i.e. crushed soybeans the oil of which is extracted) or extruded beans (i.e. soybeans processed to make them digestible) would be used to feed poultry, sold under the Duc label as well as laying hens (Lorelle, 1999a,b). It involved two production zones were concerned: one in the south-west of France, including eight cooperatives and the company, Céréol, which processes soybeans into meal; the second in Burgundy, including three cooperatives and the company Extrusel, specialized in the production of extruded seeds. In order to mitigate the risk of contamination of locally-produced soybeans by imported US beans, a cooperative from Castelnau (southwest of France) the Groupe Occitan, checked the French origin of seeds, isolated the production plots, stored the harvested beans separately until they were delivered. Regarding Extrusel, a subsidiary of four grain cooperatives of Burgundy and Franche-Comté and of two livestock-feed producers of Saône-et-Loire, it produced 20,000 tons of extruded soybeans per annum (annual turnover of about \$6.2 million). Extruded soybeans are a very digestible feed which supplies both proteins and fats and is incorporated into poultry and hog rations. In February 1999, Extrusel made the decision to only use soybeans of which the non-GM status could be guaranteed. During the spring of 1999, 8,000 hectares were sown with soybeans that were certified as non-genetically-modified by about one thousand farmers; this acreage represented the whole cultivated area between the cities of Belfort and Mâcon. A fully operational traceability system was set up from the farm to the client. Part of the beans was produced in the company's station and the rest was bought from outside suppliers with guaranteed origin, so as to be in conformity with Extrusel ISO 9002 standards (Bréhier, 1999).

Farmers who subscribed to this new productive venture and who harvested their first non-GM soybeans in the 1999 fall, sold their product at 1,100 Francs per ton (about \$177), compared with 1,000 Francs per ton of 'ordinary' soybeans and 1,300 Francs per ton of beans used for human consumption (Lorelle, 1999b).

Bourgoin imposed additional constraints on the farmers that produced the 'soja du pays'. They must not use genetically modified soybeans and they should trace the production of the beans at all stages of the process, they must grow them at a certain distance of pollution sites (e.g. chemical factories and incineration centres which could generate dioxin residues) and should refrain from spreading sludge originating from wastewater treatment. Certified poultry represented almost 85 per cent of annual total turnover of Bourgoin-Duc, and through the company's decision not to use transgenic soybeans it wished to anticipate consumers' demand. Bourgoin-Duc had already prohibited the use of transgenic maize since 1996 in the feed used for poultry. In addition Bourgoin had tried, with

food distributors such as Carrefour, to set up non-GM soybean production chains in the USA and Brazil (Lorelle, 1999a).

In addition to Glon-Sanders' poultry and eggs, labelled as 'biologically produced' and qualified as high-quality and rather expensive products, French consumers could buy another type of product labelled 'soja du pays'. But for this kind of poultry, fed with non-GMOs and offering a good safety, the consumer had to pay more (Lorelle, 1999a).

8.7 Fraud

Biological agriculture is not free from criticism because of fraud. By early 2000, in France, the agriculture ministry's Directorate-General for Competition, Consumption and Fraud Repression carried out an enquiry on false biological cereals. About a dozen important operators were involved in the following traffic: a dealer buys conventional cereals and establishes forged certificates that qualify them as derived from biological agriculture; the cereals are sold as 'bio' products either to feed producers or directly to livestock raisers. As the selling price of 'bio' cereals could be twofold of that of conventional cereals, the illegal profit could vary from 1 Franc to 50 centimes per kilo, and because of the volumes concerned the benefits could be very high. The French authorities discovered an international network involving in particular Italian capital. Conventional cereals were sometimes purchased in France and shipped – really or virtually – to Italy, Belgium or the Netherlands, from where they returned with the 'bio' label. Another traffic was initiated in Central Europe, particularly in Romania or Ukraine, and the cereals were transferred to France. On 23 March 2000, the French inspectors spotted a society based in Brittany (Carhaix), Eurograin, which they suspected of having marketed 50,000 tons of cereals of doubtful origin in 1998 and 1999. Earlier, on 3 March 2000, a public enquiry had been opened in the Vienne Department regarding 12,000 tons of cereals commercialized by Bio Alliance, a company based in Chasseneuil-du-Poitou. Its manager was condemned for having unduly used a 'bio' label on bovine meat. Another enquiry concerned the shipment of the Celtic Ambassador, a boat inspected in 1997 in Bordeaux; the 4,500 tons of cereals found in the boat officially originated from Romania, and had been certified 'bio' in the Netherlands. The enquiry showed that the shipment had been made at Fos-sur-Mer, in the southeast of France, and that the cereals were conventional French ones (Hopquin, 2000a).

Similar trafficking may crop up. It underlines the limitations of the certifying bodies, in charge of controlling the fulfilment of biological agriculture requisites through two annual visits without warning. There were three certifying organisms in France. The most important one, Ecocert, covered 80 per cent of the market; by mid-1999, it was able to detect pesticide traces in animal feed produced by Central Soya, a neighbour and client of Eurograin. Ecocert then alerted the certifying organism of Eurograin, Afaq-Ascert, which had been controlling this company since 1998. Many officials have recommended the stricter enforcement of biological agriculture requisites, considered as too loose (Hopquin, 2000a).

Fraud and the subsequent mistrust could also explain the relative slump in the consumption of 'bio' products. Another explanation of this decrease is the competition among quality labels as well as the trend toward a more environment-friendly agriculture ('rational' agriculture') that may kidnap the image relating to organic farming (Dupont, 2001).

8.8 'Rational' agriculture

"Rational" agriculture's goal is to make a compromise between productivity and environment conservation. In France, the terms of reference of this mode of agricultural production contain 98 points relating to the improvement of agricultural practices (better use of pesticides and recycling of wastes, improvement of sanitation, precise recording of farmer's practices, better prevention of animal diseases) and upkeep of farm economic profitability (Dupont, 2003).

A key issue of conventional agriculture is the better and more effective use of fertilizers by crops. Increasing the absorption and assimilation of macronutrients such as nitrogen fertilizers would therefore contribute to decreasing the percentage of these fertilizers not used by plants and therefore to drastically reduce soil and water pollution by nitrogen compounds. In this regard the work by Shuichi Yanagisawa and colleagues of the Universities of Okayama and Tokyo, published in the Proceedings of the National Academy of Sciences (PNAS) on 18 May 2004 could be very promising. The Japanese researchers were able to incorporate into the genome of *Arabidopsis thaliana* a gene from maize that improves nitrogen assimilation in this crop species. The gene transferred, Dof1, does not only control the synthesis of a protein, but also a series of genetic regulations involved in the constitution of the plant's 'skeleton'. In *Arabidopsis thaliana*, indeed, Dof1 has modified the expression of several genes: amino-acid concentration has increased, that of glucose was lowered compared with control plants, but not that of sucrose. But the most striking modification concerned the growth of the transgenic plants in an environment with limited amounts of nitrogen: control plants showed symptoms of deficiency such as bleached leaves, while transgenic plants looked normal. As a follow-up to the experiment on *Arabidopsis thaliana*, Dof1 has been transferred to potato plants by the Japanese workers; as a result, the amount of amino acids in the genetically modified plants increased. This result is promising, because potatoes are not very efficient in absorbing and assimilating nitrogen compounds; henceforth the need to add such fertilizers to this crop (Morin, 2004).

Increasing biological nitrogen fixation (instead of nitrogen fertilizer inputs) is also an objective of 'rational' agriculture. Legumes are able to fix atmospheric nitrogen thanks to symbiotic bacteria living in their root nodules (*Rhizobium*) and they need much less nitrogen fertilizers than other crop species. An international consortium is carrying out the sequencing of the genome of the annual alfalfa species, *Medicago truncatula*, considered as a model legume. This genomics work is to be finalized in 2007, but preliminary results already showed that the genomes of legumes were

remarkably conserved, i.e. the gene sequence is quite similar among the different species. About 500 genes have been identified as related to the symbiotic relationship between the legume and its rhizobia. Legume geneticists also hope to unravel the role of the Nod factor, a molecule identified by the researchers of the French National Agricultural Research Institute (INRA) in Toulouse; it has been shown that one-tenth of mg of this substance per hectare was sufficient to raise soybean yields by 11 per cent (Morin, 2004).

Although the transfer of biological nitrogen fixation to cereals is considered a remote possibility because it would involve the transfer of a few hundred genes, the immediate priority is to select the most effective legume species and varieties using genetic methods, so as to raise the percentage of peas, lupins and horsebeans grown in Europe as feed and consequently decrease the dependence of European countries on the imports of soybeans for animal feed (70 per cent of animal feed proteins were imported in 2004) from the USA, Brazil and Argentina. Another objective of the selection of more effective nitrogen-fixing legume species and varieties is to reduce water and soil pollution caused by nitrogen fertilizers (nitrates), as well as the fossil energy needed to produce these fertilizers: to produce and spray one ton of fertilizers, two tons of oil are needed (Morin, 2004).

On 8 January 2003, at the Forum of 'rational' agriculture, its president, Christiane Lambert, indicated that between 5,000 and 10,000 pioneers of 'rational' agriculture (out of over 650,000 farms in France) were willing to move to this type of agriculture. However, the main trade union of non-intensive farming, opposed to transgenic crops, the Confédération paysanne, highlighted that half of the requirements of 'rational' agriculture in fact corresponded to just the compliance with current regulations. The consumers' association UFC- Que choisir? did support the terms of reference, while the National Federation of Biological Agriculture (FNAB) was concerned about a confusion between the products of 'rational' agriculture and 'bio' products. Others fear that food processors and distributors may request the farmers to adopt 'rational' agriculture without any financial compensation, and may consequently neglect the farmers that do not move toward this mode of production. On 4 March 2003, a National Commission for Rational Agriculture and Qualification of Farms (CNARQE) has been set up in order to gradually enlist the farms devoted to this type of agriculture (Dupont, 2003).

While trying to regulate the so-called 'rational' agriculture, the French government wants to foster 'organic' agriculture. On 2 February 2004, the minister of agriculture announced a plan aimed at doing so. About €50 million over a five-year period were to be allocated to organic farmers. In addition, communication activities requiring a €4.5-million investment over three years aimed at clarifying the AB label which did not seem to be well understood by the consumer. This label means an alternative system of production that does not use chemicals, relies on antibiotics on a limited scale for livestock, that implies an extensive type of agriculture and includes crop rotations. It markets products that are certified to contain 95 per cent of ingredients derived from processes excluding the use of synthetic

chemicals. But the 'bio' label does not mean a superior taste or any health benefit (Amalou and Dupont, 2004).

About €10.8 million over three years aimed at strengthening the downstream part of 'organic' agriculture, which is handicapped by the low volumes of production and the dispersion of producers on the French territory. In addition, biological or organic agriculture will be promoted in agricultural education and research. The National Federation of Biological Agriculture (FNAB) welcomed the governmental measures, but organic farmers stressed that they were not receiving financial aid aimed at this kind of agriculture in the very short term, like other European producers (Amalou and Dupont, 2004).

8.9 The Case of Slow Food: organic farming, eating habits, taste and cultural features

The problems of organic farming may nevertheless be discounted by consumers from Europe or other reach countries on the basis of arguments relating to eating habits, taste and hedonism. Thus, Carlo Petrini, president of the association Slow Food (as an opposition to fast food), is setting up in Italy in the heart of a 300-hectare domain (where environment-friendly agriculture methods will be practised) the first world's 'university of taste'. By the end of 2003, some 400 students from the five continents were studying all the aspects of food culture in Piemonte. The ultimate goal is to train specialists that throughout the world will preach the art of good food. Supported by the revenues from a hotel and a wine bank, the university will be completely independent from the food industry. The €16 million needed for the project have been found, especially from private savings (Maurus, 2002).

C. Petrini has built a real counterpower over 14 years, starting from a village in Piemonte, but now spreading outside the Italian borders. Slow Food's symbol is the snail – slow and tasty – and its slogan is: 'eat less and eat better'; it has also a web site, publishes a review in four languages and owns an editorial house. About 75,000 persons from Europe and North America adhere to the association and all defend the gastronomic heritage which is, according to them, threatened by the homogenization of tastes, multinationals and hypermarkets (Maurus, 2002).

In October 2002, 140,000 persons attended the third Congress of Taste, organized by Slow Food in Torino. The Slow Food's prize for the defence of biodiversity was awarded to 13 farmers from Japan, Greece, Guatemala and Guinea. They all had the merit to safeguard a product, such as an old rice variety, Andean vegetables or black piglets (Maurus, 2002).

Slow Food is difficult to define: it is a non-governmental organization, a consumers' association and a gastronomic club, and the whole managed as an advanced enterprise. The objective is not to destroy private property or transgenic crop experimental plots, or to denounce steadily, but to play on pleasure, seduction and marketing, so as to successfully compete with fast-food companies and food and beverage multinationals. After having been launched in December 1989 in Paris, Slow Food was officially constituted

with 500 persons from 17 countries. A few months later, the association named 150 good-will people whose task was to set up 'conviviums', i.e. autonomous clubs, where information and experience are exchanged, products are compared and tasted. In Milan, Slow Food's editorial house publishes guides and a luxurious cultural review on recycled paper, that is sent to all the association's members. In addition to the initial goal of eating less and eating better, there is also the concern for a better environment and food safety, i.e. 'produce less and produce better'. Surfing on the wave of preoccupation caused by the 'mad-cow' disease, Slow Food has gained momentum through its 'ecogastronomic' approach (Maurus, 2002).

In 1999, Slow Food launched the 'Taste Ark': foodstuffs and products threatened with extinction, once identified by the 'conviviums', are supported by various means, e.g. promotion tools provided by the association to the farmers or producers, exhibition booths at the Salon of Torino, assistance through the media, equipment and funds levied among sponsors and local authorities. More than 150 products have thus been saved, such as San Marzano tomatoes, Ischia's rabbit, argan oil in Morocco, lama husbandry in the Andes, as well as the relevant microeconomies. In 2004, some 300 products were to be saved (Maurus, 2002).

Slow Food can claim that it has been successful in achieving its goal of advocating the importance of good food and the emphasis on maintaining and even widening the diversity of food culture, which entails an environment-friendly agriculture that includes organic farming. With 40,000 members in Italy, 9,000 in the USA, 6,000 in Germany and 3,000 in Switzerland, Slow Food is taken seriously by lobbies and big food and beverage companies. In France, the movement has taken root in the southern part of the country, but does not grow rapidly, probably because it is difficult to find a meaningful slot between gastronomy leaders and chefs, and the anti-GMOs vociferous opponents (Maurus, 2002).

References

- Amalou, F.; Dupont, G. 2004. La France veut rattraper son retard dans les produits bio. *Le Monde* (Paris), 4 February 2000, p.21.
- Apple, R.W. Jr. 2004. Survival, renewal and magic in the vineyards of Italy. New ideas for old wines in the heel of the boot. *International Herald Tribune*, 10-11 July 2004, p.20.
- Bate, R. 2000. Organic myths: the retreat from science. *Biotechnology and Development Monitor*, no.41, p.24.
- Benkimoun, P. 2004a. Prévenir les maladies coronariennes et l'obésité. Modifier les comportements nutritionnels des familles. *Le Monde* (Paris), 4 February 2004, p.28.
- Benkimoun, P. 2004b. Le vrai et le faux des omega 3. Des résultats prometteurs dans le traitement des cancers. *Le Monde* (Paris), 31 March 2004, p.26.
- Blanchard, S. 2004. L'obésité infantile « enjeu majeur de santé », ne cesse de gagner du terrain. *Le Monde* (Paris), 11-12 April 2004, p.6.
- Bréhier, A. 1999. La deuxième chance de la filière bourguignonne. *Le Monde* (Paris), 14 September 1999, p.24.
- Day, S. 2003. Keeping food tasty, minus salt and sugar. *International Herald Tribune* (New York), 2 August 2003, p.5.
- Dupont, G. 2001. La crédibilité des labels est menacée par la forte demande des consommateurs. *Le Monde* (Paris), 21 December 2001, p.13.
- Dupont, G. 2002. L'agriculture biologique traverse sa première crise. *Le Monde* (Paris), 8 November 2002, p.14.
- Dupont, G. 2003. Agriculture raisonnée: premières certifications à l'automne. *Le Monde* (Paris), 14 March 2003, p.12.
- European Commission. 2002. *Wonders of Life. Stories from life sciences research (from the Fourth and Fifth Framework Programmes)*. Luxembourg, Office of Official Publications of the European Communities, 27pp.
- Faujas, A. 2004. « Les productions AOC ne sont ni opéables ni délocalisables », Philippe Mauguin. *Le Monde* (Paris), 24 February 2004, p.III.
- Ferrie, A.M.R. 2003. Microspore breeding programmes for nutraceutical plants. *PBI Bulletin* (Plant Biotechnology Institute, NCR, Saskatoon), 1, pp. 14-15.
- Georges, F. 2003. Beneficial carbohydrates. *PBI Bulletin* (Plant Biotechnology Institute, NCR, Saskatoon), 1, p.18.
- Hopquin, B. 2000. La filière bio confrontée à une multiplication des enquêtes judiciaires. Un cahier des charges rigoureux pour respecter l'environnement *Le Monde* (Paris), 11 April 2000, p.9.
- Jones, A. 2004. Sweet success for sucralose. *Financial Times* (London), 1 July 2004, p.7.
- Juurlink, B. 2003. The beginning of the nutri-geno-proteometabolomics era of nutritional studies. *PBI Bulletin* (Plant Biotechnology Institute, NCR, Saskatoon), 1, pp. 9-13.
- Lorelle, V. 1999a. Deux industriels créent la première filière 'non OGM' en France. *Le Monde* (Paris), 2 September 1999, p.19.
- Lorelle, V. 1999b. Les pionniers du soja 'non OGM' à l'épreuve de leur première récolte. *Le Monde* (Paris), 14 September 1999, p.24.
- Lorelle, V. 2000. L'agriculture biologique, entre crise de croissance et quête identitaire. *Le Monde* (Paris), 11 April 2000, p.9.
- Maurus, V. 2002. Slow Food. *Le Monde* (Paris), 27 November 2002, p.16.
- Mola, G. 2004. En Italie, la thérapie du centre d'Atri commence par l'implication de la famille. *Le Monde* (Paris), 11-12 April 2004, p.6.
- Morin, H. 2004. Des plantes transgéniques qui se passent d'engrais ont été mises au point au Japon. *Le Monde* (Paris), 21 May 2004, p.22.
- Nau, J.-Y. 1999. Les surprises de la recherche en paternité des grands cépages français. La réglementation contre l'aventure. La belle histoire du petit gouais blanc. *Le Monde* (Paris), 16 October 1999, p.24.
- Normand, J.-M. 1999. L'alimentation bio aborde une crise de croissance. *Le Monde* (Paris), 5 November 1999, p.30.
- Roche, M. 2004. Le Prince Charles lance un shampooing bio. *Le Monde* (Paris), 25 March 2004, p.1.
- Sánchez Bardón, L. 2004. Gastronomía y salud. Gastronomy and health. *IBERIA RONDA Magazine* (Madrid), March 2004, pp.45-50.
- Sasson, A. 1990. *Feeding tomorrow's world*. Paris, UNESCO/CTA (Technical Centre for Agricultural and Rural Cooperation), 805 pp.
- Sasson, A. 2000. *Biotechnologies in developing countries: present and future. Vol.3. Regional and subregional co-operation, and joint ventures*. Paris, UNESCO, Future-oriented studies, 1,103 pp.
- Schmidt, R.H.; Rodrick, G.E. 2003. *Food Safety handbook*. 864pp.
- The Economist*. 2003. Spoilt for choice. A survey of food. *The Economist* (London), 13 December 2003, pp.11, and 3-16.
- The Economist*. 2004a. Obesity. Fat of the land. *The Economist* (London), 6 March 2004, pp. 35-36.
- The Economist*. 2004b. Agricultural biotechnology (I). Designer meat. Better breeding through biotech. *The Economist* (London), 10 July 2004, p.72.
- Zagré, N.M. ; Delpeuch, F.; Traissac, P.; Delisle, H. 2003. Red palm oil as a source of vitamin A for mothers and children: impact of a pilot project in Burkina Faso. *Public Health Nutrition*, vol.6, no.8, pp.733-742.

United Nations University Global Reach

Programmes at UNU Centre, Tokyo, Japan

Peace and Governance Programme
Environment and Sustainable Development Programme
Capacity Development and Fellowships
Online Learning
Email: mbox@hq.unu.edu, URL <http://www.unu.edu>

UNU Research and Training Centres or Programmes (RTC/Ps)

UNU Institute of Advanced Studies (UNU-IAS), Yokohama, Japan

Focus: strategic approaches to sustainable development
Email: unuias@ias.unu.edu, URL <http://www.ias.unu.edu/index.cfm>

UNU World Institute for Development Economics Research (UNU-WIDER), Helsinki, Finland

Focus: development economics
Email wider@wider.unu.edu, URL <http://www.wider.unu.edu/>

UNU Institute for New Technologies (UNU-INTECH), Maastricht, The Netherlands

Focus: socio-economic impacts of new technologies
Email: postmaster@intech.unu.edu, URL <http://www.intech.unu.edu/>

UNU Institute for Natural Resources in Africa (UNU-INRA), Accra, Ghana

Focus: natural resources management
Email: unuinra@inra.unu.edu.gh, URL <http://www.inra.unu.edu/>

UNU International Institute for Software Technology (UNU-IIST), Macau, China

Focus: software technologies for development
Email: iist@iist.unu.edu, URL <http://www.iist.unu.edu/>

UNU Programme for Biotechnology in Latin America and the Caribbean (UNU-BIOLAC), Caracas, Venezuela

Focus: biotechnology and society
Email: unu@reacciun.ve, URL <http://www.biolac.unu.edu/>

UNU International Leadership Institute (UNU-ILI), Amman, Jordan

Focus: leadership development
Email: mbox@la.unu.edu, URL <http://www.la.unu.edu/>

UNU International Network on Water, Environment and Health (UNU-INWEH), Hamilton, Canada

Focus: water, environment and human health
Email: contact@inweh.unu.edu, URL <http://www.inweh.unu.edu/>

UNU Programme on Comparative Regional Integration Studies (UNU-CRIS), Bruges, Belgium

Focus: local/global governance and regional integration
Email: info@cris.unu.edu, URL <http://www.cris.unu.edu/>

UNU Food and Nutrition Programme for Human and Social Development, Cornell University, USA

Focus: food and nutrition capacity building
Email: cg3o@cornell.edu,
URL <http://www.unu.edu/capacitybuilding/foodnutrition/cornell.html>

UNU Institute for Environment and Human Security (UNU-EHS), Bonn, Germany

Focus: environment and human security
Email: info@ehs.unu.edu; <http://www.ehs.unu.edu>

UNU Iceland-based Training Programmes: Reykjavik, Iceland

UNU Geothermal Training Programme (UNU-GTP)

Focus: geothermal research, exploration and development
Email: unugtp@os.is; <http://www.os.is/id/472>

UNU Fisheries Training Programme (UNU-FTP)

Focus: postgraduate fisheries research and development
Email: unu@hafro.is; <http://www.unuftp.is>

The United Nations University Institute of Advanced Studies (UNU-IAS) is a global think tank whose mission is “advancing knowledge and promoting learning for policy-making to meet the challenges of sustainable development”. UNU-IAS undertakes research and postgraduate education to identify and address strategic issues of concern for all humankind, for governments and decision makers and, particularly, for developing countries.

The Institute convenes expertise from disciplines such as economics, law, social and natural sciences to better understand and contribute creative solutions to pressing global concerns, with research focused on the following areas:

- Biodiplomacy,
- Sustainable Development Governance,
- Science Policy for Sustainable Development,
- Education for Sustainable Development, and
- Ecosystems and People



**UNITED NATIONS
UNIVERSITY**

UNU-IAS

Institute of Advanced Studies

United Nations University Institute of Advanced Studies (UNU-IAS)
6F International Organizations Center
Pacifico-Yokohama
1-1-1 Minato Mirai, Nishi-ku
Yokohama 220-8502
Japan

Tel: +81 45 221 2300
Fax: +81 45 221 2302
Email: unuias@ias.unu.edu
Website: www.ias.unu.edu