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Controllable development of the food sector in tropical areas: main challenges, fields of research and research procedures

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Half a century of agronomic research has shown that the problem of food sufficiency cannot be defined simply in terms of chasing after a constantly rising demographic curve and proposing more productive crop varieties. New priorities have emerged which are not solely production-oriented. The key issues in today's debate are urbanization, globalization, disparity and poverty, health risks, long-term planning, social control of technology, identity, and ethics. An analysis of these issues reveals that one of the crucial questions for the future of the planet is the relationship between production and consumption, in other words the food sector. In tropical countries the food sector is still regarded as being less important a field of research than agriculture, although these days its importance tends to be better understood. In this situation, it seems appropriate to learn from the directions followed in the past and the new approaches adopted over recent years. This diagnosis serves as a background against which to examine possible new fields of research. It also indicates the need for a reform of current research and development practices and an expansion of scientific resources in the South.

After a century of major technological progress, one of the age-old questions facing mankind is still with us: will there be enough food for everyone tomorrow? Debates over the last few years concerning the future of the planet have seen the question of food sufficiency reappear. With the world's population growing at an ever-increasing rate and an extra 1.7 million mouths to feed each week, the Malthusian fears of a widening gap between people's needs and food production are once more coming to the fore.[1] The threat of medium- or long-term hardship is directing public attention to the need for a new international effort to increase food production.

Half a century of agronomic research has shown that the problem cannot be defined simply in terms of chasing after a constantly rising demographic curve and proposing more productive crop varieties. New priorities have emerged which are not solely production-oriented. The key issues in today's debate are urbanization, globalization, disparity and poverty, health risks, long-term planning, social control of technology, identity, and ethics. These all go to show that one of the crucial questions for the future of the planet is the

relationship between production and consumption, in other words the food sector. This is the subject of the **first section** of the article.

Although the food sector has significantly contributed to ensuring food security, questions are now being asked about recent developments in the industrialized countries. The food sector is accused of being a tool used by the richer countries to establish economic and cultural domination. These countries are said to impose their own products and patterns of consumption on lesser economies, thus discouraging local production.[2] The food industry is alleged to be exposing consumers to major health risks.[3] It is criticized for its increasing lack of openness as it grows more self-contained and industrialized, for being beyond external control and for contributing to the growing loss of consumer confidence in food products. It is maintained, finally, that the food industry is making the relationship between man and nature more artificial and depriving man of the references he needs to construct his identity. If he no longer knows what he is eating, man will cease to know who he is.[4]

Why have developments in the food sector given rise to such concern? No doubt it is because food is different from other consumer products in that it passes through the body. Man is transformed by it to a greater extent than by any other product and his well-being is more directly affected. It contributes to growth and good health — but can also cause illness, or even death. It gives both sensory and social pleasure and also has a considerable effect on his sense of individual and collective identity. What is at stake in the development of the food sector therefore cannot be considered purely in economic terms. As far as food supply is concerned, long-term planning should not be focused solely on the sustainability of production systems, the protection of natural resources, pollution control and energy management. It must also include the question of changing patterns of consumption; examining not only their economic but also their social and cultural implications.

In tropical countries the food sector is still regarded as being less important a field of research than agriculture, and the primary concern has traditionally been to increase production. Its importance in agricultural development tends to be better understood these days, however, and many research institutions and development agencies have increased their investment over the last few years. It therefore seems appropriate to learn certain lessons from the experiments carried out in the food sector, and these are discussed in the **second section** of this article. This appraisal serves as a background against which to examine the fields of research that need to be explored if the future development of the food sector is to be subject to social control. This is the subject of the **third section** of the article.

It is not enough, however, merely to analyse what is at stake in the development of the food sector and translate it into research requirements. The scientific approaches used in food sector research are changing rapidly. They now attempt to take the particular nature of this sector into account, converging on a common approach: a systemic, complex analysis of each commodity, its production and use. Secondly, the research and development procedures used in the past are now being called into question. Three key failings are held to be responsible for a large number of setbacks to technological and organizational innovation, accidents even, caused by a lack of control over the consequences of innovation: each approach was associated with a different discipline; there was no communication between researchers and those using research results; and the realities of the situation were not diagnosed in sufficient detail to establish appropriate research strategies. Over the last few years new research approaches have emerged, calling for a major reform of the practices employed by researchers, development officers, extension agents and politicians. This new wave of thinking has three main aims: to focus research procedures on the users, to break down the barriers between the different disciplines and to adopt more flexible and interactive methods of management. The **fourth section** of this article examines how recent advances in scientific thinking and methodology can best be capitalized on by researchers and reflected in the future programming of their work.

Challenges facing future food supply

What precisely is meant by 'the food sector'? It can be defined as the whole range of technical, trading and service activities involved in the performance of a number of different functions:

- making food products edible, for example by removing inedible bulk (eg seed husks) or toxic parts (eg cyanogenetic compounds in cassava, and antinutritional factors such as phytates in certain pulses, which reduce the absorption of iron and calcium, or antitryptics, which inhibit digestion);
- exploiting their useful parts (eg extraction of oils, starch or flavourings);
- transporting products (packaging and shipment from the point of production to the point of consumption);
- storing products and prolonging their conservation time (eg by drying, fermentation or heat treatment);
- modifying the organoleptic, gustatory or nutritional characteristics of products and giving them particular characteristics by subjecting them to various combinations of operations (eg converting milk into cheese, converting wheat into flour, semolina, bread, pasta, biscuits or couscous) or by mixing several different products together (eg culinary preparations).

The processing of basic foodstuffs is one of the oldest activities of mankind, older even than agriculture, if we include cooking. The development of trade with distant parts and of urbanization meant that such activities gradually lost any association with domestic culinary activities and became specialized and autonomous, giving rise to numerous different occupations. Food sector activities today represent a major source of employment and income, particularly for women, in countries obtaining most of their resources from agriculture (most tropical

countries, for instance). International comparisons show that an increasing percentage of the value added from the combined agricultural and food sectors in terms of GDP/person, is attributable to the food sector. It is about 10% in the poorest countries and 50% in the richest.[5] It is thus of quite strategic importance in tropical countries, and this is accentuated by the fact that these countries are faced with a variety of different challenges. How can the food sector help to meet them?

The first challenge: demographic growth

The world's population should reach between 7.5 and 8.5 billion by the year 2020, almost four-fifths of whom will live in tropical countries. The total demand for cereals for human and animal consumption will need to have doubled by this date to about 1.7 billion tonnes.[6] This challenge basically concerns agriculture. However, the food sector can help to increase available food supplies by reducing post-harvest losses and improving the yields obtained from converting agricultural raw materials into finished foodstuffs. It is very difficult to evaluate these losses overall. They vary considerably from one country to another, but are greater in hot, wet zones and are aggravated in developing countries by a lack of adequate storage and transport infrastructures. They also vary considerably according to the perishability of the commodities concerned. Post-harvest losses of 15 to 20% are often quoted for cereals in tropical areas. These may exceed 50% and even approach 100% for more perishable commodities like roots and tubers, fruit or fish. Appreciable reductions in such losses appear possible, not only by improving storage, conservation and pest control techniques and processing yields, but also by improving transport and marketing infrastructures and organization.

The second challenge: urbanization

The rate of urbanization is particularly rapid in tropical regions and exceeds that of demographic growth. It reinforces fears of a widening gap between people's needs and long-term food production. Urbanization alters dietary behaviour. Town-dwellers eat more meat and more processed products that have a built-in service factor (convenience foods), in other words calories that cost more to obtain, and this is accentuated by their rising level of income. North Americans thus consume the equivalent of 800 kg of grain per annum, Italians 400 kg and Indians 200 kg.[7] The newly industrialized and urbanized countries are moving towards an agro-nutritional model which it appears impossible to provide for on a sustainable basis for the entire world.[8]

But the town-dwellers cannot be fed just by increasing agricultural productivity. Supplying urban centres involves first collecting and packing the produce, stabilizing it for transport and storage, processing it to adapt it to urban lifestyles, then finally distributing it.

In some countries, particularly in Africa, food imports have helped to fill the gap between urban demand and local agricultural supply, a gap created by the different rates at which these two factors are changing. But to some extent they have also had the secondary effect of restricting outlets for local commodities. Although the gap has tended to shrink over recent years,[9] the competitiveness of local produce in urban markets is nevertheless limited by three main factors: it is often not available widely enough or over a long enough period of the year, it is expensive compared with competing imported products and its quality does not always meet the new requirements of urban consumers.[10] The relationship between agricultural supply and urban demand means that intermediation activities need to be developed to influence these three factors.

The third challenge: globalization of trade

This raises the question of the competitiveness of tropical foodstuffs on the internal and international markets.

We have seen certain foodstuffs invade the urban, then rural markets of Africa, Latin America and Asia. The distribution of bread, rice, chicken, dry milk solids, beer, hamburgers and Coca-Cola has led some authors to fear that local produce will disappear and food become completely standardized.[11] They believe that the economic domination of the industrialized countries will encourage the populations of the South to adopt a Western-style pattern of consumption. This pessimistic view of worldwide dietary trends is not completely unfounded. It should be relativized, however, by recalling that it is but one aspect of a completely ambivalent movement. Concomitantly with the move towards globalization and the convergence of agro-nutritional models, local features are making their existence felt in the on-going construction of identities and in evolving dietary patterns.

Agro-nutritional models (ie the products making up the food intake) should not be confused with dietary patterns (the combinations of foods finally eaten and how one organizes oneself to do so). What separates the former from the latter is one of the most culturally determined of all creative activities: cooking, or more accurately culinary art, which is both the demonstration and the product of the diversity of mankind's tastes and pleasures. Whereas analysis of the products consumed gives the impression of convergence towards a single or dominant pattern of consumption, analysis of dietary practices reveals a considerable capacity for appropriating and reinterpreting external references through cookery and styles of consumption.[12] The celebrated 'thièbou diène' of Dakar, a rice and fish recipe that has become Senegal's national dish, is prepared using Thai rice, local fish, mainly imported vegetable oil and vegetables introduced by the Portuguese and French. But it is far from being part of 'international cuisine' and has become one of the symbols of African cuisine.

As far as dietary change is concerned, the main overall trend appears to be diversification. Particularly in urban environments, this applies both to the produce and preparations consumed, and to the methods of supply and processing and the patterns of food intake. Consumers enjoy a more varied diet and obtain their supplies from a wider range of sources, a pattern of eating away from home develops, and changes occur in the way meals are organized. In the face of this overall movement, which is very

noticeable in certain countries of the South,[13] the tropical produce and culinary preparations specific to each culture will only be able to resist the globalization of trade if their diversity is exploited and they are put to varied uses. Benin is a particularly interesting case in point: maize is processed there into forty or so different products,[14] and this in large part explains the limited penetration of imported rice and wheat. The identification of products with their country of origin is becoming an important consideration in food sector development.

As far as the international market is concerned, the competitiveness of tropical foodstuffs is not determined by price alone. Promotion of their particular organoleptic, nutritional or 'functional' qualities, is also an important factor, eg colour, flavour, smell, texture; fat, carbohydrate, protein, mineral, vitamin content; thickening, setting or coagulative properties. Price and intrinsic quality are clearly not the only factors determining the competitiveness of tropical products: the surpluses and food aid policies of the industrialized countries also have a major effect.[15] It is nevertheless the distinctive qualities of such products as coffee, cocoa, tropical fruit flavours, herbs and spices, gum arabic and the like that have made them successful. Promotion of the distinctive nature of these properties is what enables such products to conquer new markets (eg specification of cocoa or coffee quality by geographical origin); and a loss of distinctiveness can lose them markets. Coconut oil sales initially dropped on the world market as a result of the problem of aflatoxins produced by inappropriate drying processes and the cost of the refining procedures needed to remove them. The decline may subsequently be aggravated if genetically engineered industrial crops are planted in the North for the production of lauric acid fats, the particular niche occupied up to now by coconut oil. Vanilla and cane sugar are likewise faced with strong competition, the former from synthetic vanillin and the latter from artificial sweeteners.

Other examples are tropical roots and tubers (cassava, yam, sweet potato, cana, aracacha, etc), which up to now have essentially been regarded simply as sources of starch. Better development of their distinctive properties would immediately open up new markets for these products. Some of them have properties that are in great demand on the international market, as a result of the recent regulations restricting the use of modified maize starch. Little research has so far been carried out into these properties: the resistance of starch to heat treatment, for use in frozen foods or baby foods; the precise rheological behaviour required to produce analogues of fat; its rising quality in cookery; sheer strength, etc.

The fourth challenge: widening disparities

Overall, the world currently produces enough food to meet its food requirements. Over 800 million people however, ie a seventh of the world's population, do not get enough food to lead a healthy active life. At the same time, almost 400 million people are suffering from illnesses caused by dietary excess (obesity, diseases of the cardiovascular system). The first situation is the result of political instability, war and poverty. Loss of identity and confusion of the social and cultural reference points which previously helped maintain behavioural equilibria are suggested as reasons for the second.[16] In neither case does malnutrition appear as a simple question of the quantities of food available. Food security should include the notions of distribution and of sustainable access to foodstuffs for all, together with those of social and political stability, equilibrium and consistency. Overabundance of supply may be accompanied by a demand devoid of financial resources, as is currently the case in Latin America; if the gap between the two widens, food security becomes a major political problem in terms of a more equitable distribution of available resources. Witness the pillaging of supermarkets in the vicinity of the shanty-towns.

What has this to do with the food sector? Firstly, it can help improve the transportation and storage of the food resources available. Secondly, it offers opportunities for economic activity, employment and income in both rural and urban environments; and thirdly, it can play a part in reducing the cost of food production (lower losses, higher yields in terms of both materials and energy, more efficient marketing channels).

The final challenge: social control of changes

The long history of changes in the food supply situation shows that man's relationship to food and to the world of nature in general is characterized by an ambivalent and simultaneous move towards greater remoteness and greater proximity:

- greater remoteness, with the relationship becoming progressively more artificial. Food supply chains grow longer and more complex; the origin and the quality of products become increasingly difficult to identify (eg the appearance of 'Unidentified Edible Objects')[17] and to monitor; and dietary points of reference are thrown into confusion by the multiplicity of contradictory recommendations (eg those on cholesterol levels or food for babies). Industrial foodstuffs are becoming further and further removed from nature, and the move is reflected in a large-scale increase of health risks. This is accentuated by the development of mass production and distribution, and by the fact that innovations are implemented far more rapidly today than was the case in the past (depriving us of the distance required for objective evaluation). The consumer is becoming increasingly suspicious of the industrial food sector and its lack of openness. The crisis associated with the danger of bovine spongiform encephalopathy (or 'mad cow disease') being transmitted to man, is but a further episode in a series of crises which include baby milk, hormones in veal, food colourings and ionized foodstuffs in Europe, mercury in fish in Asia, and food aid cereals, flavour cubes and mangoes treated with acetylene in Africa.
- a move towards greater proximity in the consumer's relationship to his food: the development of farm produce, organically grown produce, local specialities, direct selling by the producer, and

home-grown garden produce. This is very noticeable in the countries of the South,[18] but it is also apparent in industrialized countries like France, often in reaction to the first tendency. Home-grown garden produce accounts for a quarter of the domestic consumption of fruit and vegetables in France.[19]

An awareness of these two tendencies, in both the North and the South, alters the way that changes in the food production system are seen. Rural, small-scale, decentralized processing is no longer regarded as the survival of archaic, outmoded activities which ought logically to make way for more 'rational' industrial processing. It is developing as a fundamental means by which the consumer can maintain or re-establish reference points in his relationships with others, with himself and with nature. In addition, long-term respect for the environment is becoming a consumer preoccupation, particularly as regards food: interest in foodstuffs grown by less environmentally polluting agricultural methods and in biodegradable packaging; and mistrust or even refusal of irradiated or transgenic foodstuffs, etc.[20] Over and above this, the individual as consumer is becoming a user with citizenship responsibilities.

Let us now consider the advances achieved by past lines of food sector research and development, particularly in tropical areas, together with their limits.

Food sector research and development

Increasing the level of food production has long been the primary concern of research and rural development activities in tropical areas. For over half a century most of the efforts to develop agriculture in the broad sense of the term have focused on perfecting and popularizing improved varieties and more intensive cropping and livestock systems, combating plant diseases and attacks on harvests, understanding farming system operations and smallholder strategies, encouraging farmer organizations, and the like. These efforts have in many cases born fruit and appear to require support in the face of extremely rapid demographic growth.

The food sector as the poor relation

Up to now only a very small part of the research resources has been targeted at the sector concerned with economic activities related to the processing of agricultural raw materials. The food sector remains the poor relation of tropical agricultural research in the technical, economic and social disciplines, both in the national institutions of the countries themselves and in the international research institutes and cooperation agencies. Figures for the countries of the South are scarce, but the current ratios in the most advanced institutions in the field are revealing. Senegal, for instance, has a total of 130 scientists carrying out agricultural research, but only 15 are working on food technology, and fewer than five on the socioeconomics of the various commodity chains, or of food in general. The proportion is lower in Ghana (15/152) and even at CIRAD (80/900), the world's leading scientific organization for tropical agriculture. The paucity of scientists and laboratories working in the food sector field means that it is not currently possible to meet the challenges facing this sector. A complete reorientation of agricultural research priorities is therefore required, with the aim of changing the balance of resources between the production field and that concerned with the use of the basic agricultural products. Although such a reorientation can be based on what has been learnt over the last few decades, the limits of the fields of research covered up to the present should not be overlooked. What has been learnt and what are these limits?

Processing of export crops and imported products

The first point to note is that research in the tropical food sector initially focused on industries producing export commodities for the international market (eg coffee, cocoa, palm oil, coconut, groundnut, sugar cane, tinned fish, etc), as did more strictly agricultural research in these areas. The development of tropical agriculture was essentially regarded as a matter of increasing capacity for the production of cash crops in a context where trade was becoming international (product marketing was largely done locally, however, for instance in the vegetable oil and sugar industries).

The first efforts to develop the food sector to feed the local population were aimed at establishing local industries to process imported products (wheat-flour mills, breweries and soft-drink industries, powdered milk reconstitution plants, etc). Research in this field consequently made no effort to exploit a large number of local food crops: cereals (eg millet, sorghum, maize, fonio, quinoa, tef, amaranth); tropical roots and tubers (cassava, yam, taro, sweet potato, cana, aracacha, etc); pulses (cowpea, pigeon pea, néré, etc); vegetable oils (karite, balanites, etc); fruit (cupuacu, acerole, mangostan, safou, etc); all the more so as their role in the agricultural economy, or as foodstuffs, was geographically restricted. Commercial processing of such commodities has developed with the opening up of the urban markets. However scientists are not well equipped to meet the needs of new companies wanting to obtain information on processing procedures, improve product quality or diversify product use. Such knowledge is rarely committed to paper and its dissemination remains limited, except in the case of a few major products,[21] although recent efforts in this field by a number of Southern and Northern networks deserve to be acknowledged: these are the TPA (Technologie et Partenariat Agro-alimentaire) network, Procelos (Programme Régional de Promotion des Céréales Locales au Şahel) and Redar (Red de agroindustria rural). In addition to this, very little information on experiences and results is exchanged between Africa, Latin America and Asia, even when they are dealing with the same subjects.

Efforts to develop local produce

Food sector research has only recently become interested in developing food crops for local markets. There have been two main lines of research, both aimed at feeding the urban population.

The first essentially consisted of attempts to create tropical versions of

imported products. They involved, for instance, the inclusion of millet, sorghum, or maize in traditionally wheat-based foodstuffs (bread, dough, etc). Over three-quarters of food sector research into millet and sorghum processing has been devoted to such 'compound flour' programmes.[22] Research into maize and sorghum processing has also been aimed at developing products shaped like rice grains, called 'maize rice' and 'sorghum rice'. The results have been disappointing. Very few of these ersatz products have met with commercial success in Africa or Latin America, for a variety of technical and economic reasons, but primarily because the products had a weak market position.[23] Consumers were generally unwilling to buy products that they considered to be of lower quality than the reference products, particularly when presented as direct substitutes. Various observers criticize not only the lack of success but also the ethnocentric nature of such research.[24] Talking about research to develop tropical cereals, they stress that 'the emphasis placed on compound flour has undeniably marginalized research into improving traditional procedures and the development of new products'.

The second and much more recent approach has been to industrialize the manufacture of traditional products. This has involved mechanizing the processing procedures and marketing often ready-to-cook foods which are packaged more hygienically, like industrial products, and have a more standard quality: advantages supposedly sought after by the urban consumer. Results have been varied. The strategy has had numerous successes in Latin America and Asia, where it has been primarily pursued by private food-processing groups, for example: farinha and bread-making quality cassava sour starch in Brazil, panela (brown sugar from sugarcane) and patacones (plantain crisps) in Colombia, corn meal (obtained after alkaline treatment) in Mexico, charqui (dried meat) in Brazil, tofu and tempeh (fermented soy bean curd or cake) in Indonesia, nuoc mam (fish sauce) or cana noodles in Vietnam, etc.

Similar experiments have been tried in Africa: cassava-based products like gari (grated and roasted cassava) in Togo, attiéké (a cassava product in granulated form) in the Ivory Coast, chikwangue (fermented paste) in the Congo, yam flakes in the Ivory Coast and Nigeria, millet-, sorghum- and maize-based flour, grits and granulated products in Senegal and Benin, baby food in Benin, Rwanda, Zaire and Burkina Faso, fruit juice, fruit nectar and locally-picked produce like mango, tamarind, guava and bissap in Senegal, Burkina Faso, Togo, Burundi, etc. In most cases these products have found a market, but a more limited one than expected. Only a small and largely well-to-do section of the population was prepared to pay extra for the quality advantages over domestically or traditionally produced products. Such attempts at industrialization have, in the final analysis, had little effect on feeding the most impoverished members of society who make up most of the urban and rural population in Africa and remain a very important part of it in Latin America and Asia.

Decentralized processing activities

As far as both the processing of cash crops for the international market and food crops for local markets was concerned, technology research initially focused on industrial-scale activities. Businesses on this scale appear more capable of rapidly supplying a suitable amount of produce of an appropriate quality to meet export market requirements or urban demand. In some cases, industrial technology and processing was able to learn from other subsectors where a processing industry had been developed (for instance, industrial wheat-milling processes were transferred or adapted to millet, maize and sorghum mills). With only one or two firms per country, the small number of parties involved simplified relations with the research teams and the public authorities. However, this type of business could only operate at a profit over an extended period of time under particular conditions: they needed to have satisfactory control of the supply networks, which is frequently difficult to achieve because of inadequate regulation of production and marketing, especially for food crops; and external technical assistance to bridge the gap between the technology employed and local technical resources.

Here, too, it is only recently that the strategic importance of the more decentralized enterprises, the rural agro-industries and the small-scale urban workshops in the food sector has come to be appreciated.[25] As the public authorities were often not officially notified of the existence of such activities, their contribution to the supply of processed food products was not usually taken into account. Today it is acknowledged as being essential in the food crop subsectors (roots and tubers, tropical cereals), particularly in Africa, but also in Latin America and Asia. The view of a large number of policy makers and scientists that this type of food sector was an archaic symbol of underdevelopment and technological backwardness did not help its importance to be recognized, either. In addition to its major contribution to the supply of local foodstuffs to the towns, it is worth recalling its importance in terms of job and income creation and its capacity for innovation.[26] The extremely limited interest that scientists have shown in this type of activity has led them to neglect the traditional processes used, the knowledge and skills they presuppose, the particular methods of operation of this type of enterprise, etc. Despite the dominant role that this sector plays in tropical regions, it is rather in Europe and the industrialized countries that scientists are today (re)discovering its importance.

Long-term management of the food production system

In more general terms, the faith in technological progress and industrialization that typified the 60s, 70s and 80s has distracted the attention of scientists from the questions of social control and long-term management of changes to the food production system. The effects of industrialization on Man's relationship to his food, on energy consumption, on the environment and on health risks, were neglected. Such concerns were too remote from the short-term requirements of business and of policy makers and often had ideological overtones. They have still not entered into fields of scientific research except to a marginal extent.

Let us now try to identify one or two lines of investigation for tropical food sector research to follow.

New directions for tropical food research

The directions taken by tropical food sector research in the past, it would appear from the above, have reached their limits. Previous research priorities were certainly consistent with the development strategies adopted in tropical countries, and the objectives aimed at were often achieved thanks to the results of this research: the coffee, cocoa, palm oil and coconut subsectors could not have been developed if procedures had not been established to maximize the value of such products; the importance of the food crop subsectors, the rural agro-industries and small-scale food processing would still remain unrecognized if research had not provided a better, though far from complete, understanding of such activities. Today, however, we have a different appreciation of what is at stake in developing the food production system, or a clearer one. A new balance needs to be established between the various fields of research, and new areas of work opened up.

Urbanization and agricultural development

An initial readjustment involves focusing more attention on the food crop subsectors feeding the urban populations. This has already started but a lot still remains to be done. Research needs to encourage the drive towards agricultural development provided by urbanization, following the example of the international markets and the export sectors, which have been a driving force in this development over the last few decades. Doing so, it first requires a better understanding of the urban markets: the nature of consumer behaviour and consumer expectations and how they change. What are the trends in the consumption of stabilized products in terms of fresh, refrigerated or frozen products? What are consumer expectations in terms of quality and price? Secondly, it requires a better understanding of the supply conditions under which these markets operate: how do the intermediation systems function (organization, structure, constraints, risks, uncertainties)? What conditions do they require to develop, to be competitive? How can they be improved? Finally it is necessary to develop processing techniques to adapt the quality of local agricultural raw materials to market requirements, and find ways of cutting food prices: how can the wealth and diversity of the raw materials and existing expertise best be exploited? How can they be improved and widely disseminated? How can the raw materials be put to more diversified uses?

Cutting production costs

As a further element in this readjustment programme and to meet the challenge of widening economic disparities, research must become involved in job creation in both rural and urban environments and in the reduction in food processing costs. Expanding food processing activities and producing food cheaply for underprivileged populations can help to increase income levels, particularly for women, and make food more readily available to the poorest members of society. Research and development work already carried out into rural agro-industries in Latin America,[27] street food in Asia,[28] urban agriculture[29] and small-scale food production in Africa,[30] shows the way for investigations of this type.

A more professional approach

Compared to what has so far been done in the agricultural sphere (smallholder organizations, training and advice for farmers, decentralized credit facilities), efforts to give the food sector a more professional approach have been neglected. This is a new field of research for economics, the social sciences and business studies, whose interest in this sector has up to now focused on the operation and policies of big business concerns. The diversity and complementarity of the different types of enterprise, the conditions under which they come into being, under which they operate, trade organizations, technical, financial and management training requirements; all these will need to become serious topics for research to back up their development.

Efficient use of local resources

A major field of research still in need of development involves identifying and characterizing the wide range of food technology know-how existing in the world. This wealth of expertise is put to good use in the North, but is still relatively neglected in the South. Over and above the economic problem of providing outlets for local produce, the challenge is there to exploit the diversity of Man's heritage which such resources represent. With a small number of exceptions,[31] there are few countries in the South at present familiar with their own technical resources, ie their areas of expertise and own special products, while market operators are busy developing initiatives to exploit them.

Such initiatives concern both the local and the international sectors. The people of Colombia and Brazil, for instance, know how to make a product called 'sour starch', using a combination of fermentation and sun-drying. The remarkable property of sour starch is that it can be used like wheat flour to produce leavened bread (ie with an alveolar structure) despite an absence of gluten.[32] This is not the case with other starches obtained from cereals, roots or tubers, which in the current state of technology can only be used to produce flat loaves. The development of this traditional know-how has resulted in cassava being more competitive on the local markets for starch products in these two countries. Bread rolls made with sour starch are now sold in fast food outlets in the big cities of Brazil, whereas until recently cassava had the image of being a poor man's food. It is still not known why this form of processing makes cassava starch suitable for bread-making. Scientists are currently trying to discover how to adapt the process for use with other starch products in other countries, with the twin objectives of giving added value to cereals, roots and tubers in the countries of the South and of manufacturing gluten-free foods essential to certain diets (baby food, people allergic to gluten).

Opening up new fields of research

Up to the present, when questions of technical aid were considered, little

attention was paid to the energy yield of the food production system, or to the environmental impact of its development. There is a shortage not only of data, but also of suitable methods for carrying out such assessments and providing answers to the various questions that arise: what proportion of the total energy injected into the agricultural or other sectors is used in processing, distributing and marketing the agricultural raw materials? What are the energy requirements of the different industries according to product stability (eg fresh, refrigerated, frozen, dried or sterilized products)? What is the environmental impact of these processing activities (eg water and wood requirements, pollutant effluents, by-products) in terms of the different processes used? Recent efforts in the industrialized countries to develop methods based on economic, ecological and energy balance sheets may well be paths worth exploring, even though they still have flaws.

Another field of research is the conditions required to give better social control of evolving food technologies: how can users, ie ordinary citizens, participate in the research and development process? Current research into the social control of technology[33] represents an interesting approach. It raises questions not only about long-term change in technical systems, but also about the role of research in the development process. Such an approach means that the issues examined and the objectives become inseparable from the way in which the research is carried out.

Research and development approaches

What criteria can be used to define the quality of a particular food? How can quality specifications and control be established without major expense, to satisfy demand? How can we obtain information about and anticipate this evolving demand and conquer new markets? These are some of the questions that research must address, taking into consideration both the technical and the socioeconomic dimensions of food processing and use.

Until very recently the food sector, including training, research and development, was rigorously partitioned into broad product sectors: cereals, fruit and vegetables, meat, fats, etc. It is only of late that the importance of transverse studies cutting across the various subsectors or branches of activity (processing operations such as drying or heat treatment, marketing, packaging, consumption, etc) has become apparent in the food technology field,[34] under the impetus of expanding major industrial sectors such as chemicals. The breakdown of these divisions is responsible for the very recent development of new scientific approaches in the field of product exploitation. It is striking that these developments have in common the application of a systemic, complex, transdisciplinary approach,[35] in all fields of technology and socio-economics, and in every discipline. Such convergence is not fortuitous. It is the logical result of identifying the limits of the approaches applied in the past and part of a searching re-examination of research practices. Such developments are not without consequence for the future of food sector research and development centres in general (national institutions in both the North and the South and international institutions), a future which needs to be prepared for right now.

A transdisciplinary approach

Looked at even in strictly technical terms, foodstuffs cannot be reduced to an inert assembly of biochemical substances (carbohydrates, fats, proteins, acids, cellulose and pectin, aromas or minerals). They are also living, and therefore unstable systems characterized by dynamic interactions between the different components and a multitude of reactions that develop in a spontaneous and disorganized fashion from the time of harvest, if they are plant products, or death, if they are animal products: enzyme reactions (eg phenoloxydase activity in plants, protease and lipase activity in animal products); microbiological reactions (eg bacteria, yeasts, moulds); biochemical reactions (eg oxidation).

These interactions have among other things led to the development of new sensorial evaluation techniques to supplement information obtained by instrumental techniques for assessing foodstuff quality (composition, texture, etc). They have also made it necessary to establish more general indicators than the traditional analytical criteria. Water content, for example, is not usually an adequate indicator to characterize the suitability of foodstuffs for conservation. There is an increasing tendency today to use physical stability (eg glass transition temperature) or physicochemical stability indicators (eg water activity) to determine, for instance, physical or physicochemical stability status (eg water activity) for foodstuff storage.

This move towards more systemic, more complex approaches is even more explicit in the field of processing procedures. The new discipline of process engineering[36] has developed alongside the traditional academic approaches of mathematics, physics, chemistry, etc, with models favouring a transverse approach which is systemic, complex and also transdisciplinary.

Operations like drying, freezing, pasteurization, crushing and formulation all involve mass transfer (eg water evaporation, solute diffusion), heat transfer or momentum transfer (eg in connection with a fluid flowing around a solid) and biochemical or physicochemical reactions. It is therefore useful to study such operations in themselves, independently of the substances to which they are applied. In-depth knowledge of the mechanisms governing mass and heat transfer during convection drying can be used in wood and rubber applications as well as those for fruit, meat or fish, for both small- and industrial-scale activities. For this reason the concept of the 'unit operation' has been devised, referring to an operation common to a large number of sectors.[37] Moreover, transfers and reactions characterizing different unit operations are usually linked together and occur in complex structures (plant or animal tissues). It is often impossible to give an adequate account of the general nature of a process if the 'irreducible' interactions and links (ie those that cannot be broken down into simple parts) are ignored.[38] Faced with systems too complex to describe using the traditional analytical approach, process engineering has had to establish more

all-embracing quantitative methods of approach, of a systemic nature, which focus on behaviours rather than structures.[39]

If one wants to influence a process, it is essential to take into consideration all the constraints associated both with the particular characteristics of the raw material used (which is where food science is of major importance), and with the socio-economic environment[40] in which the technology will operate. This is the contribution of the approaches focusing on technical systems,[41] which identify relationships between man, materials and tools (equipment or processes). It is this which distinguishes what Le Goff[42] has termed 'rural process engineering' from 'computerized process engineering', the privileged domain of the more industrialized countries.

In the same way, we cannot fully appreciate the significance of a particular foodstuff unless we take into account the way in which it is used: in combination with other foods in culinary preparations, themselves arranged into meals which have different functions according to the time of day. The way in which the food is perceived also depends on the context in which the individual consumes it, on his environment, his history and his identity. In other words, it is a social and historical construct. The development of representation models, likewise complex and systemic, means that the different factors determining perception and learning phenomena are taken into consideration. This type of approach is ultimately far more fruitful than traditional analytical approaches on their own. It gives a fuller account of reality in that it takes interactions into consideration, and it therefore provides scientific criteria which are more useful for action.

Food science or consumer science tries to understand and to manage technical, social or economic factors determining food quality, and process engineering attempts to answer the questions: how can a particular substance be given the required properties? How can this be done with the minimum investment or operating costs? Which of the substance's properties should be measured and controlled (for example by varietal selection, technical production processes, harvesting methods, etc) in order to predict its behaviour during the operations required to process it? This indicates the extent to which the three approaches are interrelated and explains the disquiet felt in research and development centres and training institutes working in the food sector. It is felt both in the North, where such approaches are used too independently of one another, and in the South, where the existing research resources are usually devoted to the food science approach, to the detriment of the other two.

This anxiety is aggravated by inadequate links with the upstream agricultural decision-makers and with the associated scientific disciplines (agronomy, varietal selection and the like).

Towards action-oriented research

Up to a decade ago, food sector research was mainly programmed 'from upstream'. The main priority was to increase production, and processing appeared as a later stage, during which the raw material produced acquired added value. Since then an opposing view has been advanced, proposing that food sector research should be programmed 'from downstream', ie from the marketplace. This involved identifying end-user requirements and demand in order to focus the attention of the processing channels on the actual outlets or even redefine the products themselves.[43] The supporters of 'downstream decision-making' hoped to stimulate production by giving farmers guaranteed outlets for their produce. Thanks to this new way of thinking, which is now gaining the upper hand, the possibility exists of adjusting the balance between the different approaches. But downstream decision-making was a reaction to upstream decision-making and both had a common weakness: a linear view of commodity chains.

Today analysis of the setbacks suffered in the past and the new approaches themselves both indicate the necessity of taking upstream and downstream constraints and leverage into consideration simultaneously when identifying the location of log-jams in the various commodity chains and ranking them in order of importance. The idea of the commodity chain is evolving into one of an intermediation system, where the interactions between the different operations (production, storage, transportation, marketing, processing, use) are recognized, as are the relationships between them. Varietal selection of tropical species should thus take suitability for processing into consideration more systematically, as well as yield and resistance to disease.[44] Likewise, the methods of marketing different products in any one agricultural region are interrelated. New expertise in processing one product can lead to improvements in another area of expertise used with another product. In the scientific field, this type of approach demands that the points of view of several different disciplines (agronomy, technology, economics, sociology, etc) be brought together.

In fact, the convergence of scientific approaches in the food sector, which involves both the engineering sciences and socioeconomics, could today facilitate interdisciplinary dialogue and lead to genuinely transdisciplinary rather than just multidisciplinary approaches[45] right from the start of the analytical stages preceding research project design.

Research into innovation management has also shown the necessity to get beyond the pros and cons of upstream and downstream decision-making.[46] Innovation should be regarded not just as an object but also as a process. The traditional sequential model of exploration, feasibility, industrialization, launch, production and evaluation must be revised and move towards a type of 'simultaneous engineering' which brings together all the partners (research, marketing, development, financers) in any project right from the start, along with their various objectives, tools and methods.[47] Negotiation then becomes the driving force behind the innovation process[48] and the scientist becomes involved in the action.

It is obviously much easier to put forward the possibility of action-oriented research than to carry it out! Communication between scientific disciplines is quite hard, but communication between scientists and market operators is even harder. To help overcome these difficulties, the scientific and business sectors have

developed various concepts and methods to manage the multi-disciplinary and interactive aspects of programming and implementing research and development projects. For instance, functional analysis and value analysis methods have introduced new practices for product and equipment design and project management. Such tools make it possible to establish areas of negotiation between the different actors and require each party to acknowledge the aim of the other parties.

Conclusion

With the appearance of renewed concern about food security problems, and in a context characterized by the globalization of trade and unprecedented demographic growth and urbanization, the development of the food sector in the countries of the South appears to be one of the key issues affecting world stability. The sector's expansion in the countries of the South remains problematical, however, owing to the lack of competitiveness of companies and tropical products in local and export markets.

Greater research capabilities and wider technical, management and economic support in this sector are essential for its development. This calls for the full commitment of the national research institutions, the international research centres or the cooperation agencies, who currently devote only a very small part of their potential to the food sector.

Some resources are already being mobilized, and it now seems crucial to establish an international forum of ideas to design a consistent global system, taking into account the achievements and limits of past experience and new scientific approaches in the food technology field.

But the use of complex methods and management of transdisciplinarity and interactivity is not merely a matter of method. Properly trained people are also needed, and it is currently felt in both North and South that there is a certain shortage in this field.

The use of systemic, complex, transdisciplinary approaches clearly also demands an in-depth knowledge of local resources (human, technical, agricultural, etc) and constraints (structure and operational methods of companies and industries, etc), and proximity between the actors concerned. This shows the inadequacy of trying to develop the food sector in the countries of the South by simple technology transfer and argues in favour of establishing a fully-fledged research and development system there.

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