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Discussion Paper 2

for

UNIDO PROGRAMME ON TECHNOLOGIES FOR HUMANITY : A BIOMASS-BASED STRATEGY

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Cultivation technology for the benefit of rural development

A. Big or small?

As indicated in discussion paper no. 1, there are many reasons to visualize that a future "biosociety" will require a two-ties structure where large production units, making full use of the economy of scale and the advances in advanced technologies, are combined with small and simple decentralized facilities. As bread-making illustrates this is certainly nothing new, but man's ability to genetically modify and to store unicns biocatalysts and perishable materials opens many new possibilities. Some of those are already exploited by the food-industry in the industrialized countries. They have actually shown a great capacity to adjust both to technical (convenience foods) and social innovations (franchising). It is also an industry which illustrates that there are many factors that keep the growth of production units in check:

- the trend towards increased national and regional self-reliance;
- diminishing world trade;
- increased vulnerability both of society and company (strikes, social upheavals, wars, breakdown in services or hygiene, etc.)
- rising transport costs for raw materials, waste and products;
- increased use of decentralized energy sources;
- the pressure to recycle waste to agriculture;
- environmental legislation;
- increased demands for job satisfaction;
- cheaper and more reliable automation;
- cheaper and better telecommunications;
- cheaper and better information storage and retrieval.

Obviously, every society will have to find its own balance between large-scale and small-scale activities. However, there are many good reasons why the planners in developing countries should question a development pattern where the production of a few export crops not only increases the economic vulnerability of society but also pushes untold numbers of small farmers into shantytowns.

Even if the upgrading of a more diversified biomass base might eventually lead to a distribution of buying power that could help to restrain the spectre of unemployment and explosive urbanization, the first priority must be rural self-sufficiency in food. As a rule, this is visualized in terms of better seeds, fertilizer and irrigation, but as indicated in discussion paper 1, there are many areas where the contribution from biotechnology and genetic engineering can be substantial. Here there will be only mentioned:
First, I will talk about plant tissue cell culture as an example of the application of advanced laboratory techniques. Then I will discuss the potential inpact of improvements in the field of food fermentations.

B. Plant tissue cell culture

We have to admit that many of the current problems in the industrialized world can be traced directly back to the tunnel-vision of a specialization, and that is something which developing countries can ill afford. What their scientists must realize is that there are certain high-technology fields, like plant tissue culture, where the applications can generate fairly quick rewards.

M.R. Sondahl, W.R. Sharp and D.A. Evans (DNA Plant Technology Corp. 2611, Branch Pike, Cinnaminson, NJ 08077) for instance recently distinguished between the following research areas from the point of view of their applications:

A. Near-term applications (up to three years)
   1. vegetative propagation
   2. disease elimination
   3. germplasm exchange/storage

B. Mid-term applications (three to eight years)
   1. somaclonal variation
   2. gametoclonal variation
   3. embryac rescue
   4. in vitro fertilization
   5. another culture and haploid production

C. Long-term applications (eight to 15 years)

1. somatic hybridization
2. hybrids
3. mutant cell lines
4. organelle transfer
5. chromosome transfer
6. gene transfer
7. plant secondary metabolites by fermentation

There are, in fact, already many examples of successful application which illustrate the relevance of such techniques to developing countries, quite irrespectively if we call them plant science or biotechnology (="the application of scientific and engineering principles to living cells to provide goods on a commercial scale").

The IDRC supported virus-elimation from cassava, carried out at Saskatoon, is just one example among many.

Del Monte Corp. for instance now has the capability of producing one million banana plants per year by in vitro procedures, and micropropagated pineapples are also being field grown. Meristem culture of pineapple axillary bud explants have yielded a 1000 - 100.000 X multiplication rate compared with a 5 - 10 X multiplication rate achievable with the best conventional vegetative propagation techniques.

Tissue culture has also been used to select for resistance to Panama Disease, a serious banana disease caused by a Fusarium. Detection of resistenat plants normally takes a long time, but Del Monte can now detect fusaric-acid resistant clones in 60 days by tissue culture.

It is of course great that companies like Del Monte can improve bananas and pineapples and that Native Plants Inc. has the resources to work on rust-resistant coffee and new clones of tea (now so slow that new selections are released only once in 20 years). However, I personally prefer indigenous efforts, like those of R. Madrigal of the Universidad Autonoma Chapingo in Mexico, where 92.000 acres of coffee plants are now infected with orange leaf rust. True enough, this can be controlled with fungicide, but this would cost US$500, and the annual coffee income of the smaller farmer is only US$300.

It should be remembered that "of the 120,000 coffee farmers in Mexico, 98,000 produce 81 per cent of the nation's crop on holdings less than five ha. Recent statistics show that 45 per cent of the farmers there live in dwellings with only a dirt floor, 54 per cent in shacks with corrugated iron roofs, and 80 per cent in dwellings with rough plank or adobe walls. Fourty-four per cent transport their produce by draft animals, and 21 per cent on their own shoulders. Any catastrophe factor affecting coffee production would have serious socio-economic repercussions" (cited from an IDRC-project on the control of the coffee berry borer.

C. Quality - the key to dispersed industrial activities based on biotechnology

Quite obviously, the new plant nuiches and biological control agents that would be of value to small farmers would have to be developed and tested in advanced facilities. Also the manufacturing, quality control and distribution would require resources that are beyond those available at the rural level. Obviously, then a substantial impact will be required but also much patience, because radically new approaches take a long time to be accepted in tradition-bound societies. However, there exists a number of ancient practices related to the fermentation of foods and beverages which ought to pave the way, towards a gradual acceptance of improvements. Those might derive from a number of sources: For instance, improved methods for pretreatment of substrates, better knowledge about microbial ecology, increased availability of suitable materials and knowledge about the design of simple and cheap reactions, new techniques for genetic upgrading, and so on. However, it must be realized that most of the possible improvements depend on the existence of a system for quality control both with regard to the inocula and to the nutritional value and safety of the product. From this point of view the responsibility for the developments in this field ought to rest with a competent organization that could also act as a forum for the crop-fertilization which an international exchange of information about traditional fermented foods is certain to generate.

D. Mushroom cultivation

The cultivation of edible mushrooms is the only currently available simple method to convert lignocellulosic waste into a valuable and popular human food. Fresh mushrooms of the types Azaricus, Volveriella and Pleurotus generally contain more than 3 per cent protein. They have a nutritional index of 28 versus 25 for milk and 31 for soybeans. Their index for essential aminoacids is around 89 as compared with 91 for milk. Those figures are quoted from K.H. Steinkraus ("Fermented Foods, Feeds and Beverages". Biotech. Advs.1,31,1983) who also reminds us of the following:

> "One kilogram of dry composting material will yield as much as one kilogram of fresh mushrooms in three or four flushes over a period of 30 to 45 days. Usual yield is 600-750 grams of fresh mushrooms/kg dry compost. Considering that there are an estimated 2325 million tons of straw produced per year (FAO,1977) over half of which is burned, straw could be used as a substrate to produce approximately 1511 million tons of fresh mushrooms (65 per cent efficiency) or 336 kg of fresh mushrooms annually for each of the present 4.5 billion human inhabitants of the earth (920g fresh mushrooms containing about 28 g of protein per person/day)".

As illustrated by the practices in the Philippines, the production of strawmushrooms is appropriate for inexperienced farmers and can be carried out both as a small scale farm activity or as a semi-industrial operation. A reliable supply of good spann is, however, required.

The fact that mushroom cultivation is reasonably simple should not make anybody believe that there is no room for R and D. Actually, the basic physiology of differentiation is not well understood and it is very likely that control of the thermophilic microorganisms that play a crucial role in the important final stages of composting might give an impressive divident.

E. Fermented foods

There are many reasons why UNIDO should pay close attention to the potential of fermented foods. However, one should always keep in mind that low-cost, ease of preparation, safety, digestibility and even therapeutic properties may not be enough to ensure acceptability where the food is unknown. After all, it took youghurt a long time (and the addition of fruits) to make it a great business success in the western world, where soy sauce, tempe and miso now follow suit (Wood, B.J.B. "Introduction of new fermented foods into western culture". In: Advances in Biotechnology II. M. Moo-Young et al (Eds). Pergamon Press, pp.467-472, 1981).

On the other hand, if one is forced to lower the sights and settle for a process that yields a good fodder, this should not be regarded as a failure. The reason is simply that when the wholesomeness of a product aimed at animals is generally accepted, it may find its way into the human diet not only indirectly. Modern dog foods have been known to be consumed by poor pensioners in rich countries, and the nutritional value of some petfoods probably easily matches that of certain spaghetti sauce bases.

Indigenous fermented foods consist of microbial protein grown on edible substances, like soybean, peanut, rice and other cereals, vegetables and fish. They include fermented milks and cheeses as well as alcoholic and non-alcoholic beverages.

According to Steinkraus (K.H. Steinkraus "Solid-state/solid-substrate/food-beverage fermentation involving fungi. Acta Biotechnologica (DDR), 1983). They are classified into:

1. Solid-state/solid substrate (no free moisture);
2. Solid-substrate-submerged;
3. Semi-solid substrate;
4. Semi-solid-substrate-submerged;
5. Pulverized substrate-submerged;
6. Submerged (substrate in solution).

This classification is important, because it underlines the fact that much of the mass-transfer and gas-transfer theory that has been developed by bioengineers in the last couple of decades is of limited value since so much of this work has been concerned with the classical stirred stainless steel fermentor. This has, no doubt, detracted attention from the simplified designs which might do good service in the micro-aerophilic or anoerobic processes that dominate food fermentations.

Those fermentations often involve prteolysis that yields a mixture oi aminoacids and peptides which give the product a meat-like flavour, irrespectively of whether it is based on vegetable proteins (Chinese soy sauce or Japanese miso) or on fish and shrimps (Philippines patis and begoong). Certain fungi also give a meat-like fibrous structure to the product (Indonesian tempe and oncom) and yet others owe their high acceptability to a production of organic acids (sauerkraut or pickes) or alcohol (beers and wines).

An authorative comprehensive handbook has been published by Steinkraus ("Handbook of Indigenous Fermented Foods, Marcel Dekker, 1983). This underlines the important role often played by Lacto bacilli and it shows that a wealth of information exists about some of the products, for instance Tempeh which is based on grain/legumes. Another product based on similar substrates is the Indian Iddi which utilizes Leuconortoc mesentnides which might ugrade the sulphur-containing aminoacid content in the legumes. However, the nutritional aspects are often of less importance then improving the "beany" taste of legume foods. This is for instance the case with the fermentation of the African locust bean. The product (Daddawn or Dawadawn), which in this case seems to become enriched with thiamin and ribo-flavour is the cheapest form of protein (after groundnut) that is available in Nigeria. It is there used as a flavouring additive to soups and stews.

The most extensively used flavouring additive in the world (possibly excluding another microbiological product: glutonic acid). It is, however, soy sauce. This exists in a number of varieties and is based on glutinous rice or soybeans fermented in salt brine. Other types of rice products are

Indonesian Tape, Malaysian Tapai and Thai Koamag, which are all sweet/sour products highly appreciated as desserts in Asia.

Considering the number of fermented foods that are known, it is remarkable that this important group of nutrients has largely been neglected by numerical toxononists, bioengineers and genetic engineers. Fairly simple computer-aided techniques for studying very complex mixtures of microorganisms are now available (I. Kühn, MIRCEN-Stockholm), specialists on applied microbiology show interest in some food fermentations with a significant development potential, like African Gari (A.J. Sinsky, MIT) and many genetic engineers have shown great ingenuity when it comes to manipulating yeasts. However, one is forced to ask: where is the market force that will compete with the pharmaceutical and chemical industry to the services of such experts?

F. Conclusion

There are five basic reasons for UNIDO to initiate co-operative research in the fields mentioned:

1. They can make good use of the most important agents for change in nutritional habits and food preparation : women.
2. They provide an area for trends - on training in hygienic practices.
3. They open a gateway for biotechnological innovations related also to improved composting techniques, seed inoculation and waste management.
4. They exemplify "techniques for humanity" both by defining a target for transnational and transdisciplinary co-operation and by being directly relevant to the most underprevileged groups in society.
5. They are under-researched in relation to their potential. Normally they depend on the metabolic activity of natural mixtures of microorganisms which develop under circumstances (acidity or high salt concentrations) where the appearance of pathogens or toxic substances is prevented. However, many cases are known where

fermented foods have "gone bad" and caused serious illnesses or even deaths, consequently modifications and technical improvements must be closely monitored. However, routines for this exist, so one should not hesitate to initiate studies in areas such as:

- population dynamics in traditional food fermentation processes;
- opportunities to mimic the natural processes by pure cultures with various known characteristics including the capacity to produce antibiolially active substances, to produce organic acids or to tolerate high self concentrations;
- possibilities to improve the established pretreatment techniques (dehulling, steaming, grinding, luctic acid pre-fermentation, etc.);
- possibility to improve desirable characteristics of important strains;
- techniques for stabilizing and distributing of inocula;
- potential of new reaction designs and principles, for instance, disposable plastic bag reactors, ferro-cement or vegetable fiber reinforced cement vessels (for instance, pneumatic forming according to MIRCEN-Stockholm), plastic linings for wood barrels, chemical or biochemical desinfection of equipment, simple sterilization techniques for substrates based on rain water, wood ashes and buffalo urine or other sources, etc.