WORLD EMPLOYMENT PROGRAMME RESEARCH

Working Paper

Technology and Employment Programme

BIOTECHNOLOGY TO COMBAT MALNUTRITION
IN NIGERIA

by

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35339

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November 1988

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ISBN 92-2-106899-4

First published 1988

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PREFACE

Within the framework of the Technology and Employment Programme, this study is the first in a series on forecasting the socio-economic and employment effects of specific biotechnologies in developing countries. While this study focuses on biotechnology application in the animal feed industry, the others broadly cover food and export crops, edible plant-oils processing, the dairy industry, agriculture and agro-industries within a multi-disciplinary framework of analysis using both micro and macro level data.¹

The major objectives of the study by Dr. G.U. Okereke of the Agricultural Biotechnology Research Laboratory, Anambra State University of Technology, Enugu, Nigeria, are: (a) to assess the economic and technical potential of biotechnology application in the animal feed industry; (b) to examine biotechnology's contribution to combatting protein malnutrition and facilitating import substitution; (c) to examine the socio-economic and employment implications of the use of biotechnology; and (d) to review policies and measures to promote the diffusion of biotechnology.

In response to the need for meaningful in-depth location-specific studies on biotechnology, the author focuses on a specific biotechnology in the animal feed industry, the Single Cell Protein (SCP) production. The SCP technology uses a range of micro-organisms in combination with a substrate hydrocarbon (natural gas) available indigenously in abundance (lower cost compared to other substrates such as crop or wood residues) to produce animal feed, whose crude protein content is 60 per cent upwards, compared to which conventional feed, such as soy meal, contains 45 per cent crude protein.

The deployment of this biotechnology (SCP) will help alleviate protein malnutrition in general and animal protein intake deficiency in particular.² The economic climate for the promotion of this technology is favourable as can be seen from the following: (a) the income elasticity of demand for poultry products is higher than that for beef; (b) the supply-demand projections to 1990 reveal an excess demand for poultry products; (c) relative prices of other sources of poultry feed (soybean and fish meal) are higher and on the increase; and (d) the ban on the import of poultry products and poultry feed provides the protection and opportunity for import substitution.

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1. These include a conceptual piece, an overview of plant-oils processing, a comparative study between Mexico and the U.S.A. on impact of specific biotechnologies in the sugar and dairy industries, overall rural employment implications in China, the Philippines and Mexico and diffusion studies for specific commercial and export crops in Malawi and Kenya.
 2. It is estimated that the average per capita animal protein intake in Nigeria is 8.3 grams as compared to the recommended level of 25 grams.

The survey of feed millers clearly demonstrates the effectiveness of pricing policy of SCP relative to those of traditional sources of animal feed to induce substitution of the latter by the former. The study sheds light on the constraints to the diffusion of this technology. It shows that the feed millers will benefit from reduced costs of production and the consumers will benefit from the corresponding lower prices and higher quality of poultry products. In addition to creation of jobs directly, the SCP technology would enhance aggregate employment through a strengthening of the backward linkages in the system of production, processing, marketing and distribution. This biotechnology would indirectly help reduce malnutrition as the use of SCP as animal feed would release vegetable sources of protein for human consumption.

Iftikhar Ahmed

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BIOTECHNOLOGY TO COMBAT MALNUTRITION IN NIGERIA

NUTRITION AND BIOTECHNOLOGY

The overall food demand in Nigeria is estimated to be growing at the rate of at least 3.5 per cent per annum due to the combined effects of population and income growth, while available data concerning the protein requirements of the Nigerian population show that the present production of food protein falls far short of demand.¹ The intake of protein in Nigeria is 20-25 per cent below the satisfactory level,² while the average per capita total daily protein intake in Nigeria was 54 grams out of which only 8.3 grams were of animal origin.³ This value of animal protein intake is much below the 25 grams recommended out of a total protein requirement of between 65 and 75 grams. It is estimated that 1.68 million tonnes of beef would be needed annually to raise animal protein intake in Nigeria to 25 grams per capita per day.⁴ This is hardly possible in view of the present stationary or even declining cattle population, low productivity and small body size of indigenous livestock.

In recent years the expansion of meat production in Nigeria has been mainly in poultry production. The poultry industry has a greater contribution to make in filling this wide gap of protein requirement in the Nigerian diet. This is because poultry has a relatively shorter "gestation" period than the other classes of livestock. Also poultry products are more accessible and acceptable to Nigerians of different income brackets. Nigeria in recent years has entered a period of increasing food shortage. Thus protein as an animal feed component will indeed become increasingly scarce and expensive. Abnormal climatic conditions are largely responsible for the sharp fall in protein availability. It was the abnormal protein supply conditions prevailing in the mid-1960s that led to rapid development of the technology of Single Cell Protein (SCP) production.⁵ SCP is a rich source of protein which can be used as a supplement to animal feed for chickens (broilers and laying hens), calves, sheep and farmed fish. When compared to conventional feeds such as soybean meal, SCP has a significantly higher crude protein content (Table 1) and better rate of metabolisable energy. On a net protein value basis, it is estimated that a unit of SCP is equivalent to 2.15 to 2.26 units of soybean meal.⁶

SCP is now widely accepted for use in a variety of animal and some human foods.^{7,8} SCP production would reduce Nigeria's heavy dependence on imports of animal feed protein without massive developments in agriculture. It has been stated that the solution to balancing the supply and demand of protein is not just the import of more food, whether SCP or other food products by protein short countries, but in the development of technologies in these countries so that they will be able to produce more food.⁹

The introduction of the SCP technology into Nigeria, which principally has an agricultural economy would have many interrelated social and economic implications. As with any new industrial project, SCP has to demonstrate that it is commercially viable. This viability will depend on demand, production costs and competitiveness with conventional protein.¹⁰

Table 1

Compositions of representative single-cell proteins

SCP	Substrate	Composition (wt%)				
		Crude Protein	True Protein	Lysine	Methio-nine	Fats
Bacteria	Methanol	80	65	5.8	2.2	8
	Methane	60	50	4.3	3.0	10
Yeast	n-paraffin	60	53	7.4	1.8	9
	Gas oil	69	60	7.8	1.6	2
	Ethanol	54	45	6.7	1.5	6
Fungi	Carbohydrate	35-40	30-40	6.5	1.5	5
Algae	CO ₂	45-60	40-50	4.6	1.4	5
Fish meal		60-65	50-60	7.0	2.6	5-10
Soy meal		45-50	40-45	6.5	1.4	1.5

Source: Schwartz, R.D. and Leathen, W.W. Petroleum microbiology, in Industrial Microbiology (ed.) Miller and Litalcy, 1978. McGraw Hill Book Company.

The British Petroleum Company (BP) which was the first to enter into commercial production of microbial food and feed, in 1974 shut down most of its plants in various countries because of high crude oil prices, low soy and fish meal prices and various health problems caused by eating food produced on hydrocarbons.¹¹

Also, Gulf that initially entered into the field of microbial feed production abandoned their plans for commercialisation several years ago based on economic considerations.¹² Therefore, a study has to be carried out on the economic viability of SCP including such considerations as its capacity to substitute soybean, availability of raw materials for the production of SCP and the size of its market.

SINGLE CELL PROTEIN TECHNOLOGY

In the 1950s and 1960s concern grew about the "food gap" between the developed and the developing parts of the world, especially as there was rapid and continuing population growth in the latter. As a result of this concern, alternate and unconventional sources of food were sought. It was recognised that protein malnutrition is usually far more severe than that of other foods. The hope was that micro-organisms would help meet the world's protein deficiency. It was not thought that SCP would replace the need to increase

proteins from plants such as oil beans or from animals such as fish. However, the limitations of conventional sources of proteins were recognised. These include: (a) possible crop failure due to unfavourable climatic conditions in the case of plants; (b) the need to allow a time lapse for the replenishment of stock in the case of fish; and (c) the limited land available for farming in the case of plant production.

On the other hand, the production of SCP had a number of attractive features: (a) it was not subject to the vicissitudes of the weather and could therefore be produced all year round. It does not require use of soil, neither does it require large space; and (b) micro-organisms have more rapid growth than plants and animals. The biggest economic attraction is the ability of these micro-organisms to utilise waste products such as petroleum by-products as the raw material substrate. In terms of nutrient content, it has a high protein content, between 60 and 70 per cent (Table 1). The protein content is much higher than that found in plant and even animal sources.

A switch to SCP is itself not entirely free of constraints. One of the most obvious is that many developing countries, where protein malnutrition actually exists, lack the expertise and/or the financial resources to develop the highly capital-intensive fermentation industries involved. But this shortcoming can be bridged by the use of improvised fermentors and recovery methods which do not require sophisticated equipment. Other criticisms of SCP are that micro-organisms contain high levels of RNA and that its consumption could lead to uric acid accumulation, kidney stone formation and gout.

As had been stated earlier, micro-organisms began receiving attention as catalysers of food on a world-wide basis in the late 1950s and early 1960s. Nevertheless, they have for centuries been consumed in large amounts, either wholly or as part of a meal or alcoholic beverage by man, although he did not always recognise this. In many tropical countries, palm wine and sorghum beers, which have high suspensions of bacteria and yeast, have been consumed for centuries.

MICRO-ORGANISMS USED IN SCP PRODUCTION

A list of selected micro-organisms currently used in SCP production is given in Table 2. Organisms to be used in SCP production should have the following properties:

- (a) Absence of pathogenicity and toxicity: It is obvious that the large-scale cultivation of organisms which are pathogenic to animals or plants could pose a great threat to health and therefore should be avoided. The organism should not contain or produce toxic or carcinogenic materials.
- (b) Protein quality and content: The amount of protein in the organism should not only be high but should contain as much as possible of the amino-acids required by man.
- (c) Digestibility and organoleptic qualities: The organism should not only be digestible, but it should possess acceptable taste and aroma.
- (d) Growth rate: It must grow rapidly in a cheap, easily available medium.
- (e) Adaptability to unusual environmental conditions: In order to eliminate contaminants and hence reduce the cost of production, environmental conditions which are antagonistic to possible contaminants are often

advantageous. Thus, strains which grow at low pH conditions or at high temperatures are often chosen.

Table 2
Status of micro-organisms for SCP

Name	Status
Saccharomyces	Food, accepted if grown on sugars (including whey) or ethanol (even if petrochemical based); feed, general acceptance.
Candida, Hansenula	Wide acceptance as feed.
Paecilomyces	Accepted as feed.
Pseudomonas	Yet to be approved as feed.
Fusarium	Awaiting FAO approval as feed.
Aspergillus	Test evaluation completed.
Kluyveromyces	Feed.

Source: Adapted from Kristiansen and Bu'Lock: Developments in industrial fungal biotechnology in Fungal Biotechnology (1980).

SUBSTRATE AVAILABILITY

The choice of substrate for microbial protein production will depend on the availability of suitable substrate in a particular country. For example, hydrocarbon may still be the main and cheapest carbon source for SCP production in the Middle East where other carbon sources (non hydrocarbons) are in limited supply.¹³ Crop residues (straw) may be the best choice for India, Bangladesh, Mexico, Pakistan and Indonesia; and sugarcane bagasse for Brazil, Cuba and India.¹⁴ On the other hand, forest residues may be the best choice for Canada and other countries.¹⁵

The possible substrates for SCP production can be classified under three major groups, i.e. energy source materials - natural gas, n-alkanes, gas-oil, methanol, ethanol and acetic acid, renewable source materials - starch, sugar and cellulose and waste material. Figure 1 shows details of the different waste materials and micro-organisms potentially available for SCP production.

The continuous increase in concern over environmental pollution has resulted in greater negative cost values of wastes and hence has increased their potentials as SCP substrates. Carbohydrate substrates (sugars from molasses or crop residues) are the cheapest sources of carbon for SCP production indicating that carbohydrates as C source are the best choice for SCP production when compared with n-paraffins, methanol, methane and ethanol.¹⁶ Cellulosic agricultural wastes are available in large amounts in

Nigeria. They are usually of little economic value, and are non-toxic. However, they are usually widely scattered and any process which aims at utilising them must take into account the cost of collecting, transporting and storing them, as well as the fact that they vary widely in their content of cellulose and other materials. It is ironic that the tropical countries of the world, which may be expected to have large amounts of plant wastes and which are also the areas most critically hit by protein shortage, usually do not have the manpower and finance to purchase, or expertise to run, its fermentation equipment. Nigeria could develop SCP technology that use labour intensive fermentor methods and other equipment fashioned from relatively cheap materials. The importance of the Nigerian petroleum and natural gas resources compels the development of SCP technology as well as mobilisation of human resources for the working of these resources at a pace consistent with Nigerian economic development. With proven reserves of about 19 million barrels of oil (and about 115 billion barrels of potential oil reserves) Nigeria controls about 34 per cent of Africa's total reserves and about 3.2 per cent of the entire world's proven reserve.¹⁷ It has also been estimated that Nigeria's gas potential is enormous, probably exceeded only by those of the USSR, Iran and Algeria.¹⁸

ECONOMIC AND SOCIAL IMPLICATIONS OF SCP TECHNOLOGY

The importance or utility of any process depends upon its economics. It must be profitable to be commercially developed and industrially widespread. The future of SCP as a protein source for feed is involved not only in current supply and demand but also in the great protein needs of the future.

One factor that influences the demand for animal protein is the growth in per capita income of the consuming nation. The oil wealth in Nigeria and the consequent economic development it engendered tended to increase the purchasing power of her population during the oil booming period.

Estimates by experts in the Federal Ministry of Agriculture (Table 3) show that the income elasticity of demand for beef is 0.9 while that of poultry is 1.2 and for egg it is 1.0. The same source also showed that the demand for proteinous food like beef, goat meat, poultry, etc., was on the increase and that by 1985, per capita consumption was projected to double what it was in 1968.

In this section the projected demand for poultry products will be considered as factors affecting them would indirectly affect the demand for poultry feed stock which would also affect SCP production (a proxy for feed poultry). The demand for poultry feed is a derived demand in the sense that only poultry farmers would need the feed for their chickens. The demand for feed (SCP) would largely depend on the nature of the poultry industry and willingness of people to go into poultry and other livestock production. Table 4 shows the projected potential demand for poultry and egg and Table 5 shows the projected supply up to 1990.

These projections glaringly show that the demand in poultry and poultry products is greater than the projected supply. For the period covered, hence the potential demand for poultry feed is established. The oil glut of the 1980s and acute shortage of foreign exchange in 1983, which led to imposition of import restriction, dealt a severe blow to the poultry industry. The price of maize rose from N250.00 per tonne in 1983 to over N1,000.00 per tonne in 1984, but because so many farmers, including feed millers, later went into direct production, the price of maize had to drop up to N500.00 per tonne in 1987. Apart from maize which the farmers have overcome, prices of every other

Figure 1: Substrates for production of SCP from classes of micro-organisms

Table 3

Projection of demand for protein foodstuffs in Nigeria: 1968-1985

Meat type	Kilograms per capita per annum				
	Income elasticity	1968	1975	1980	1985
Beef	0.9	3.338	4.329	4.795	5.336
Goat meet	0.9	1.840	2.386	2.643	2.941
Mutton and lamb	0.9	0.422	0.548	0.609	0.675
Poultry	1.2	0.839	1.217	1.406	1.616
Pork	0.6	0.482	0.522	0.577	0.612
Offal	0.6	6.454	7.385	7.728	8.197
Bush meat	0.8	3.704	4.416	4.809	5.279
Fish	1.0	13.379	18.044	20.275	22.806
Egg	1.0	0.839	1.132	1.271	1.432

Source: Olayide, S.O., Dupe Olatunbosun, E.O., Idusoge and Ablagom, J.D. A quantative analysis of food requirements, supplies and demands in Nigeria, 1965-1985. Federal Department of Agriculture, Lagos, 1972.

ingredient in poultry feeds, especially groundnut cake, soybean, meal, wheat offals, vitamin premixes, etc., have been increased astronomically. This is so because of the excessive import of vegetable oil, the oil millers were forced to charge the value of their unsaleable locally produced vegetable oil onto groundnut cake and soymeal which is the cheapest source of protein available in this country. Also, the high cost of poultry feeds (Table 6) has become so excessive that the poultry farmers can no longer purchase feeds to produce eggs and chickens at a price the housewife can afford.

The trend in the prices of these raw materials over the years reflected the trend in the changes in the various national fiscal policies of the Federal Government of Nigeria.

This upward trend in prices of the various raw materials for feed production directly affected the prices of the different feeds as shown in Table 6. These prices drastically diminished the profit expectation of poultry projects. The poultry farmers problems were further worsened by the very poor quality of the feeds.

Table 4

Poultry meat and egg demand in Nigeria - Projections to 1990

Product	Actual Estimates 1977/78 (million kg)	Projections (Million kg)			Average Annual Growth Rate (1978- 1990)	Average Annual Growth Rate (1978- 1990)
		1979/80	1984/85	1989/90		
Poultry meat demand	88.98	99.21	119.23	143.32	4.86	4.70
Poultry egg demand	247.34	275.72	331.42	398.35	4.86	4.70

Source: Federal Livestock Department, Lagos, 1979: Economic Analysis of the Nigerian Poultry Industry.

Table 5

Poultry meat and egg supply in Nigeria - Projections to 1990

Product	Actual Estimates 1977/78 (million kg)	Projections (Million kg)			Average Annual Growth Rate (1978- 1990)	Average Annual Growth Rate (1978- 1990)
		1979/80	1984/85	1989/90		
Poultry meat supply	67.72	71.64	79.18	87.70	2.42	2.26
Poultry egg supply	254.16	266.44	289.75	316.62	2.00	1.89

Source: Federal Livestock Department, Lagos, 1979: Economic Analysis of the Nigerian Poultry Industry.

Table 6

Average price increases of poultry feeds from 1983 to 1987

Type of feed (concentrate)	Price of 25kg bag		Per cent increase
	1983 N	1987 N	
Broiler	15	58	286
Grower	11	33	200
Chick	9	60	567
Layers	18	46	156
Breeders	12	52	333
Broiler starter mash	12	28	133
Growers mash	9	20	122
Chick mash	11	25	127
Layers mash	11	22	100
Broiler finisher	11	25	127

Source: Field survey, 1988.

As a result of high feed prices and other management problems most firms operated their plant below 50 per cent of their capacity while others have completely closed down. This led to high average cost of production and the high price of product in the market. The high price of production affected the ability of the product to compete favourably in the market as well as the market strategy to be applied in the marketing process.

The poultry feed supply problem is aggravated by the poor distribution of infrastructure. Every poultry producer wants to be assured of a steady, unfailing supply of fresh nutritive and palatable feed. Short supply of feed encourages hoarding of compounded feed. Yet these feeds tend to go rancid after about a fortnight, reducing the palatability and productive efficiency.

The probability of harmful moulds growing on the feed also increases, thus hurting many producers even more. In addition, many mixers have insufficient technical training in feed compounding and manufacturing. Some of the feed millers, who attempt to maintain high quality, run into trouble when they are unable to obtain some of the essential ingredients such as soybean and fish meal. Any attempt to improve the present level of poultry development in the country must give consideration to food availability and cost. Unfortunately, evidence shows that poultry producers have been handicapped by the insufficient and irregular supplies of poultry feed. Moreover, as the cost of feeds in poultry production amounts to about 65 per cent of the total costs, this means that the failure of the feed industry implies the failure of the poultry industry.

The preferred type of protein was also considered, nearly 78 per cent of the respondents chose soybeans first, but 72 per cent chose SCP second. The fact that most respondents preferred soybean was not unexpected. To date, no SCP is available in commercial quantities in Nigeria, and since the processor is familiar with soybean products, he is more likely to respond to them. Generally, it is known that human beings tend to resist change. These results suggest that the SCP producer must educate the processor about the relative value of SCP as a food ingredient. If SCP is to be accepted with a minimum of delay (independent of the safety question) the ways in which it will be used, its economic benefits as well as the potential problems that might arise if it is used improperly must be thoroughly considered. To achieve this the reactions of the feed millers and the possible consumers of products containing SCP must be determined.

Most respondents were ready to incorporate the SCP in their feeds, as long as the product is nutritious and safe. This assurance is given by the fact that large scale feeding in some industrialised countries have demonstrated that problems of acceptance and toxicity can be overcome with care and special processing.

In a survey of feed millers, in Nigeria it was found that, ceteris paribus, the substitution of SCP for plant protein sources would vary depending on the price of SCP relative to those of traditional sources. For example, if SCP is sold at the same price as the traditional protein sources, 69.2 per cent of the millers would effect at least, 41 per cent substitution (Table 7). The single highest category was the 41-60 per cent substitution indicated by 38.5 per cent of the feed millers.

Table 7

Substitution of SCP for traditional sources of proteins when
the costs are the same

Amount of substitution %	Respondents		
	No.	%	Cumulative %
100	3	11.5	11.5
61 - 99	5	19.2	30.7
41 - 60	10	38.5	69.2
21 - 40	3	11.5	80.7
11 - 20	5	19.2	99.9
TOTAL	26	99.9	

Source: Field Survey, 1988.

However, where the SCP is about 10 per cent more expensive (even if more available), the substitution changed (Table 8). The single highest category was 21-40 per cent indicated by 42.3 per cent of the respondents. Here only 23.1 per cent of the respondent feed millers would substitute 40 per cent or more of their traditional protein sources with SCP.

Table 8

Substitution of SCP for traditional sources of proteins when SCP
is 10 per cent more expensive

Amount of substitution %	Respondents		
	No.	%	Cumulative %
100	2	7.7	7.7
61 - 99	0	0.0	7.7
41 - 60	4	15.4	23.1
21 - 40	11	42.3	65.4
11 - 20	6	23.1	88.5
5 - 10	3	11.5	100.0
TOTAL	26	100.0	

Source: Field Survey, 1988.

If the price of the SCP were, however, 10 per cent less than that of the conventional sources, then 54.2 per cent of the feed millers would go for 100 per cent substitution (Table 9). In fact, 83.4 per cent of the millers would go for, at least, 41 per cent substitution. Thus, the price of the SCP relative to that of the traditional protein sources is a critical factor in the adoption of SCP by livestock feed millers.

Another important factor is the availability of SCP. As Table 10 shows, even when SCP and traditional protein sources cost the same, more feed millers would use SCP instead of the traditional protein sources (compare Table 8 with 10).

The Nigerian feed millers are also concerned about the safety of SCP, its nutritive value, cost and flavour. Survey results show that their first concern was the nutritive value of SCP in terms of egg yield of layers, weight gain of broilers in particular, and chickens in general.

The second in importance was the safety of SCP in terms of the health of the chickens. The third was cost since cost is closely associated with profitability. With feed prices rising slower than feed input costs, the profit margin is being squeezed. Flavour was also important to the feed millers, although this factor was rated fourth, behind the other three already mentioned factors. Nearly 70 per cent called for public education about SCP

Table 9

Substitution of SCP for traditional protein sources when the SCP
costs 10 per cent less

Amount of substitution %	Respondents		
	No.	%	Cumulative %
100	13	54.2	54.2
61 - 99	4	16.7	70.9
41 - 60	3	12.5	83.4
21 - 40	3	12.5	95.9
11 - 20	0	0.0	95.9
5 - 10	1	4.2	100.1
TOTAL	24	100.1	

Source: Field Survey, 1988.

Table 10

Substitution of SCP for traditional protein sources when the SCP
costs the same as the traditional sources, but is more available

Amount of substitution %	Respondents		
	No.	%	Cumulative %
100	9	37.5	37.5
61 - 99	3	12.5	50.0
41 - 60	8	33.3	83.3
21 - 40	3	12.5	95.8
11 - 20	0	0.0	95.8
5 - 10	0	0.0	95.8
TOTAL	24	100.0	

Source: Field Survey, 1988.

to enhance its adoption by both the millers and the chicken producers. SCP can be used either for animals or for human beings as long as impurities or compounds that might be considered as health hazards are removed.¹⁹ This requirement is important as it has been mentioned that *Candida* sp has approximately 8 per cent of RNA which causes metabolic disturbance when taken without any prior treatment.²⁰ Most of the technical problems of SCP production have been solved in countries such as Kuwait and other developed countries. Extensive nutritional and toxicological studies conducted on the SCP product from both pilot and full-scale plants have proved it to be safe, highly nutritious and of good quality.²¹

BENEFICIARIES OF SCP TECHNOLOGY

The primary beneficiaries of the introduction of SCP into Nigeria include poultry farmers, consumers, feed millers and government poultry farmers who will benefit from consistent and available plant protein sources which indirectly imply constantly available high quality feeds. As mentioned earlier, many poultry farmers went out of business because of low quality feeds and non-availability of feeds. Low quality feeds meant that, for example, their broilers had to be kept beyond the optimal number of weeks. This led to a fall in profit, and often losses. That is, many farmers produced in stage III of the production function. Also, the layers did not start laying until after seven months instead of the usual five months. Even when they started to lay, the egg production efficiency was less than 50 per cent.

Feed millers will benefit from the availability and consistence of the SCP. With the ban on the import of grains and other feed ingredients, many feed millers went out of business owing to lack of raw materials. This situation will be removed since the raw materials for the production of SCP will be based on raw materials available locally. Furthermore, the feeds produced in Nigeria were inconsistent in terms of nutrient composition. When protein components became scarce, the millers simply increased the carbohydrate proportion, and the unscrupulous ones were even known to include saw dust. Also, even when the protein components were available, the percentage protein content varied from consignment to consignment. Thus, the consistency expected from SCP will remove this problem.

Consumers are expected to benefit from reduced costs arising from increased productivity of layers, broilers and other chicken enterprises. For example, improved quality feeds will reduce the age at point-of-lay from about eight months (with bad feeds) to five months. Also, the egg laying efficiency could increase to 80 per cent or more with good management. The same positive increases are expected in broiler production and other chicken enterprises. Consumers will also benefit from higher quality poultry and poultry products, as well as from the increased availability of these products.

The Government will benefit indirectly through the acquisition of SCP technology by Nigerians, reduced cost of poultry and poultry products, increased activity in the poultry sub-sector (employment, income, investment and profit), and a healthier population. The employment and income gains will be derived from forward and backward linkages in the system. The production of SCP will involve inputs locally generated. The demand for these inputs will cause increased supply of these inputs resulting in the employment of people involved in their production, collection, transportation and storage. At the production stage, skilled, semi-skilled and unskilled Nigerians will be employed to man the machinery (plant), to conduct research, etc. Once

production is complete, the output will be distributed to feed mills and other farms where these outputs will become inputs. Production in these firms will involve labour. In fact, the employment and income generating prospects of the introduction of the SCP technology into the Nigerian economy can be traced from the input supply stage to the poultry consumption stage (the final product). The largest employers of labour are expected to be the poultry producing and processing sub-sectors through expanded activities. Of course, its impact on employment and income will depend, in the final analysis, on the extent of its adoption. In the poultry sector, it has been found that labour constitutes 10 per cent of the total cost of production.²²

Increasing SCP for animal feeds would therefore improve human nutrition rather quickly by taking vegetable sources of protein out of the human/animal competition and making them available for human consumption in Nigeria. In the face of uncertain crop yields and the ever increasing Nigerian population and demand for poultry products, SCP will attract the feed millers because it is a product of consistent composition with good biological value, which can be produced under highly controlled conditions and is independent of soil and climate. Because of the proven enormous potential of the SCP products, as shown by reports from the developed countries, SCP production, if practised in Nigeria, will supply the ever dwindling feed industry with good quality proteins that will not only fill the deficit created by escalation of protein prices, especially soybean, during the last few years but create more jobs in Nigeria. It will not lead to unemployment because the producers of vegetable feeds will now produce for human consumption. This will reduce the price of soybean as there will be no competition for it from the feed millers point of view.

POLICY IMPLICATIONS

The role of government in the development of SCP technology is discussed under the following broad headings:

- (a) Provision of resources.
- (b) Diffusion and commercialisation of SCP technology.
- (c) Research and development (R & D).

Provision of resources

The most basic requirement from government is obviously the provision of resources. It is well known that SCP technology is extremely capital intensive and thus demands heavy financial investment. Such financial investment is required for providing the necessary physical facilities necessary for training and research and development (R & D) activities. It is also obvious that both training and research activities are non-revenue yielding, and development work which would, on the other hand, yield revenue eventually, has to be heavily subsidised initially. For instance, the actual cost of producing a prototype of a newly developed fermenter for SCP production may be several times the cost of a similar fermenter which has reached the stage of mass production. Even a new fermenter on mass production would still cost more than an older alternative which has had a wider and more established market. Therefore, if government is committed to the acquisition of SCP technological know-how, then it should give meaningful financial support to such an effort.

The next kind of resource that is also essential for the development of SCP technology capability is the industrial environment. This serves two purposes. First, at the manpower training stage, an industrial environment such as workshops, construction sites, design offices, laboratories, etc., provides the facility for the student/trainee to translate and relate his verbal instruction to practice and thus consolidate such concepts and acquire the related skills. The second purpose which an industrial environment serves is that it facilitates the advancement of the technology with which this former student/trainee is by now conversant. The provision of the industrial environment is therefore crucial for effective and expedient development of SCP technology capability.

Two ways are suggested here through which government can provide this resource. The first is to persuade established industrial organisations, through attractive financial incentives, to be keenly involved in industrial manpower training and also to actively engage in development work over and above their routine profit yielding production operations. Secondly, governments should undertake a radical review of its conception of the objective of the SCP project and the approach to its accomplishment. At present, the objective of a project is conceived only in terms of its functionality. Thus, the objective of erecting an SCP plant, for example, is only for mass production of SCP. This attitude does not take full cognisance of the country's technological backwardness and the need to develop indigenous capability. It is therefore necessary that the development of capability should also be considered at least as of equal importance with the functionality aspect.

Diffusion of SCP technology and product

The diffusion of technology should be given a high priority alongside the dual aspirations for acquisition and indigenous development of technology. The fact is that diffusion of technology is a more potent factor in the promotion of entrepreneurial skills.

Evolving the SCP technology and products and its quick dissemination requires a series of integrated and communicable linked systems among agencies. This involves three sub-systems: (a) Research system, responsible for generating and evolving new SCP technology; (b) Linking system, responsible for transfer of new technology, facilitating its adoption and also bringing back the field problems to research system (feedback); and (c) The client system (feed millers and poultry farmers), the ultimate users of the SCP technology and production. It is important that all the components of the complex systems are simultaneously improved and their interaction facilitated to provide the feed miller with all the available knowledge and production facilities to achieve high production levels.

The electronic media, i.e. radio, TV and mobile film units, etc., if applied judiciously, can be very effective in communicating the SCP technology and products to the feed millers and poultry farmers. TV, in particular, is a very effective medium for educating poultry farmers on safety and use of the SCP compounded feed materials in poultry production.

The best educator for the poultry farmers in a community can be fellow farmers especially the opinion leaders who have reputations for efficient production and who have adopted the SCP technology. These opinion leaders should be used initially to try the SCP containing feeds as a sort of on-farm trial in the farmers environment. Interview with these successful poultry farmers, who have used the SCP compounded feed, on radio and TV, especially describing the details of various special operations and tackling problems

often faced by the poultry farmers using SCP feed, would go a long way in helping other poultry farmers to accept SCP compounded feed in their poultry production.

Figure 2 shows the different ways the new SCP technology can be communicated to the end users (feed millers and poultry farmers). The SCP technology also reaches the end user through publications containing technical recommendations in local languages in the form of bulletins, handbooks on packages of practices folders and leaflets.

Training is another important method of imparting knowledge and skill to poultry feed millers and farmers about the new SCP technology and will help its quick dissemination. The research institutes and universities involved in the SCP technology should organise and conduct production and problem orientated training programmes on SCP. These programmes should be practical in nature and the trainees should be provided with the opportunity of learning by doing. Long-term training programmes should also be organised periodically so that the users and producers of SCP will go through all the operations of SCP production and use.

There are a number of problems that can hinder the commercialisation of improved SCP technology. These include lack of management capacity for small-scale enterprises utilising SCP technology, lack of access to finance, and market competition with imported technology and products. The average Nigerian entrepreneur lacks adequate capital to provide necessary equipment as well as infrastructure like water and electricity for mass production of goods and services with improved or developed indigenous technology. Because of capital limitation, the indigenous entrepreneur may be unable to attract the right calibre of managerial and technical staff to ensure the success of the SCP project.

There should be a National Research Development Corporation (NRDC) in the Ministry of Science and Technology charged with the responsibility of promoting, amongst other things, the commercial exploitation of SCP patents and the know-how originating from all sources especially R & D institutions funded by the public. The main objectives of the Corporation will be:

- (a) Transferring technology (SCP) and licensing know-how developed in the R & D institutions in the country to industries; and
- (b) Promoting development projects in collaboration with the private sector.

Another strategy is for the NRDC to establish a number of SCP pilot plants/demonstration units under the scheme of "Developmental projects" with a view to making laboratory know-how viable for commercial exploitation. Under this scheme, the NRDC should contribute up to 50 per cent of the total cost of the developmental project, the rest being invested by the collaborator. When the project is successful, the collaborator has to pay back NRDC's share of investment by easy instalments and the developed SCP process will be licensed to the collaborator on liberal terms.

When the developed process is licensed to other parties, the royalties collected from the parties are shared between NRDC and the first collaborator. If the project is a failure, NRDC's share of expenditure is written off and the collaborator need not pay NRDC's share of expenditure.

The other strategies which may be adopted by government for effective diffusion of the SCP technology are stated below.

Figure 2: System for dissemination of SCP Technology and product

In one joint strategy, the government provides all or part of the capital investment and mandates the private firm to manage the production facility and distribution system. This takes advantage of the private company's administrative and marketing skills and the government's financial resources. By decreasing the firm's initial investment, it becomes possible to increase (return on investment) without excessively high profit levels. Here the government is reducing the investment risk of the private firm but capitalising on its own expertise.

Alternatively, the government could reduce the firm's market risk by guaranteeing the purchase of a portion of the SCP product for its institutional programmes. Here the government takes advantage of the company's production, quality control and distribution skills. Parts of both approaches were employed by the Indian Government which designed a protein-rich food, Bal Ahar, and then used the private flour mills and groundnut processors to produce the product for institutional feeding programmes.

A third approach uses a public sector institution to carry out preliminary research and product design to develop the protein-rich food. The product is then licensed to private sector food companies for production and marketing. This was the path followed by the Institute for Nutrition for Central America and Panama in its development of Incaparina. In some countries, notably Colombia, the marketing of Incaparina then was facilitated by government media support.

In some cases, of course, the government elects to take on the entire task of development, production, and marketing. However, even in these cases the government might well draw upon private sector skills. When the Indian Government established a public sector corporation to produce and market a new enriched bread, for example, it still used private market research and advertising firms to carry out initial survey work and to design its mass communications programme.

These examples illustrate the broad spectrum of possibilities for government-private sector interaction to maximise effectiveness in dealing with problems of SCP production and commercialisation.

Research and development (R & D)

In a developing society the commitment to use science and technology for development must be accompanied by an intensive activity related to the generation of technical manpower through appropriate education policies, setting up of R & D institutions, formulation of policies for the generation and adaptation of SCP technology, and formulation of policies providing for mandatory linkages of R & D institutions with the productive sector of the economy, etc. There is no short cut to the development of the biotechnology of SCP production. The impetus for this technological take-off can only be realised through government or private sector funded research. To create the environment that encourages local R & D work, the government must establish long-term policies that would not only provide sufficient financial incentives for the SCP investments but also would provide the many other resources required for the private sector to undertake such ventures. The following sections outline a few of the broad categories of governmental policies which influence R & D investment. These policies are found today to be just as influential to the continuing support of R & D in the industrial west as they are necessary to the developing country such as Nigeria. For the sake of convenience, such governmental policies are categorised in four broad groups: subsidy, catalytic investment, education and regulation.

Subsidy

Investment in the R & D industry can be supported by either direct or indirect government subsidies. Direct subsidies by government can take the form of certain tax credits or cost sharings - which in certain cases could cover the full cost. Indirect subsidies are often in terms of such policies as patent rights which can give the company or the individual a certain period of monopoly in lieu of the disclosure of the process. Patent policies and their implementation can have a profound impact on the development of the SCP technology. The exclusive rights given to an individual or a firm to develop and market a product without any competition for a reasonable length of time can have significant impact on the R & D work in a country.

Catalytic investment

Other important governmental actions which will indirectly affect R & D efforts of SCP within Nigeria is catalytic investments by the government. Many of the investments that help build the technological infrastructure of a country must have the catalytic effect which help promote or facilitate R & D.

Education

Governmental policy regarding education can have a profound and lasting impact upon R & D activities. Such policies normally create and support the educational systems at the primary and secondary levels. Higher education nurtures technology not only by supplying the trained scientists, engineers and other specialised individuals who create and apply the technology, but the universities are also the major source of basic research, upon which all technology depends. The importance of our universities and colleges as the fountain-head of our technological growth cannot be over-emphasised.

Regulation

Regulation is a category of policies which may act either as deterrents or as incentives - although it does sometimes seem easier to use this method to discourage rather than to encourage technology investment. For example, monopoly regulation should, in principle, protect a society from excesses, whether they be in industry, labour or government. Historically, such regulations appear to be somewhat selective.

Regulations for resource conservation, whether concerned with human resources or with natural resources, need to be analysed accurately with regard to their possible consequences in encouraging or discouraging long-term R & D investment. This category of regulations, which includes increasingly strict safety or environmental rules, often acts selectively to discourage the small investor since his capital outlay is limited and the market potential for his product unknown. This type of regulation must, in general, be passed with utmost care lest it destroy much of the entrepreneurial potential that exists within the population.

Another set of regulations that can have both positive and negative influence is protective tariffs. These regulations are normally enacted for the short-term protection of local industry. They must be implemented with great care or they will protect the inefficiencies of the local industry at the expense of local consumers.

Of all the regulations listed, only those offering tax credits to encourage investment are clearly for the purpose of providing an incentive for capital. It is highly desirable that the regulatory climate be relatively

free from changes and instabilities of interpretation. R & D thrives in an environment which is free from uncertainty. Regulatory policies in general should be handled with the greatest restraint, lest the deterrents totally inundate the incentives. In short, a bad law may be worse than no law at all.

The importance of university-industry interaction

Assuming that conditions have been established to promote long-range R & D investment in SCP technology in Nigeria and that such programmes have begun in the private sector, then much has to be done to maintain the health of these investments both in terms of quality and long-term viability. One of the important factors that can influence the quality and the prosperity of R & D work in industry is the proximity and strong interaction of the R & D staff with the academic institutions. By and large, universities, research institutes and colleges are the primary institutions in which most countries conduct their basic research and where expertise and knowledge in various technical areas are developed and nurtured. Most, if not all, such institutions carry out their research work through various grants which they receive from the government. It is therefore natural to expect that they provide technical help in the form of expert consultants or actual work in support of local firms. Moreover, universities have a major stake in promoting good relations with local industries since most of their students may eventually seek employment in such establishments. Similarly, industry needs the basic research that is performed in the universities in order to extend the application of its technologies to their potential limit for further growth. Therefore, a good relationship between industry and universities is of mutual interest and must be promoted by various means, either through the urging of the government or other financial inducements.

An important factor which must be taken into account in considering the lack of R & D effort in our industrial sector, is the absence of linkages between R & D laboratories and industry. A detailed analysis of the entire process ranging from research, development, design, manufacture and marketing of products, known as the "innovation chain", has shown that it is not sufficient to develop a product in a research laboratory and then expect that it would result in an economically viable and marketable product. There are a series of efforts involved in between and each one of them requires much attention and more resources than what is required in the first stage of research. Unfortunately, in developing countries, the cultures which exist in various establishments concerned with the innovation chain, such as universities, research institutes, etc., are very different and tend to inhibit the mobility of personnel from one structure to another. Furthermore, very often there is a lack of communication between the personnel working in one section of the innovation chain and that of the other. It is, therefore, important for policy-makers in government to bear in mind that any attempt at the development of scientific and technological self-reliance can only progress if close linkages are forged between the various links of an innovation chain.

If SCP technology is to have the widest desirable results it must be appropriate to the needs, resources and capabilities of the bulk of the small firms. Since small poultry farmers and feed millers cannot enforce their technological demand in the market-place, their technological needs can be met only if the government leads research, development and policy in SCP technology.

CONCLUSION

It is expected that the market need for SCP will continue to rise as the demand for poultry products which is an animal protein source for the majority of the urban and rural population in Nigeria also continue to rise. To allocate funds to import poultry products would constitute a severe drain on the foreign exchange reserve of the country. In realisation of this the Federal Government of Nigeria has promulgated a decree banning such food and feed imports into the country, hence the need to look into alternative sources of protein for compounding feed for the poultry industry is very obvious. Also, recent high prices of fish meal and soybean meal help to support that there is and will be a market for SCP in Nigeria. SCP will complement vegetable proteins in order to help improve the dwindling feed and poultry production in Nigeria.

There are several reasons why SCP production provides a potentially valuable alternative protein production system in Nigeria. The crude protein content of SCP ranges from 60 per cent upwards, compared with 45 per cent for soy meal and an average of 65 per cent for fishmeal.²³ Nigeria, as one of the worlds leading producers of the raw materials for SCP production, stands a better chance in terms of ready availability of one of the major substrates (natural gas) which at present is being flared to the tune of 400,000 barrels equivalent of petroleum roughly \$15,000,000 every day.²⁴ Gas which so far has not yet been efficiently exploited can be recovered and utilised in the SCP production especially with the current import ban on some food materials in Nigeria.

SCP production may constitute a very attractive alternative for those countries with hydrocarbon-based resources that have a weak agriculture and most important the desire to be more self-sufficient in animal production.²⁵

Nigeria has these qualities and therefore SCP technology is likely to be a successful and adoptable technology in the country. The SCP research in Nigeria shall enable the development of new techniques for the growth of micro-organisms that effectively utilise the abundant wasted by-products of petroleum and waste materials. The research and development of SCP will, therefore, be targetted towards the specific end of a technically and commercially successful process. This is with the ultimate aim of producing high protein feed-stuff components, in sufficient quantity to complement the use of soy meal and fish meals in the diets of intensively farmed animals such as poultry. The R & D strategy for the development of SCP in developing countries should not be based on direct economic returns in the short run but rather on long-term planning and should recognise the need to achieve self-sufficiency in food supplies to foster independence.²⁶

As SCP research and development has not been widely carried out in Nigeria it is being suggested that part of the R & D programme should follow the following steps:

- (a) Isolation of SCP bacteria and substrate.
- (b) Studies on the physiology and growth characteristics of promising cultures.
- (c) Pilot production facilities for scale-up and technology development.
- (d) Studies on cell recovery and drying processes.
- (e) Nutritional and toxicological studies.

The development of SCP production could be suggested as an additional and/or complementary route to food conversion by domestic animals, but not necessarily as the exclusive way of solving the problem of food demand and consumption.²⁷ This is in agreement with what has been established by the protein advisory group of the United Nations, that "the protein from micro-organisms offers the best hope for a new source of major protein, independent from agriculture."¹¹

The establishment of SCP projects would serve the greatest number of rural poor, and provide a large part of their needs of food, income and employment. The benefits of the SCP should be seen in terms of the socio-economic needs of the poultry farmer, feed miller, government and their family, e.g. from the point of view of their nutrition, food security, employment and income.

In a developing society such as in Nigeria, the commitment to use SCP technology for compounding poultry feed must be accompanied by an intensive activity related to the generation of technical manpower through appropriate education policies, setting up of R & D institutions, formulation of policies for the generation and transfer and adaptation of the SCP technology.

One of the possible approaches to commercialising SCP technology could be through government assistance to entrepreneurs to bear the risk elements involved in commercialisation of the new technology. The government could set up a technology production company in collaboration with private firms to manufacture and market such technology on a commercial basis. The government may later sell out its shares to private companies and entrepreneurs, after the risk phase has passed. In carrying out such a programme the government may enact various laws aimed at protecting the market for such technology or product.

If Nigeria directs her interests towards developing the SCP technology and product for poultry feed production, the much orchestrated and anticipated food crisis and protein malnutrition, as a result of the rapid population growth rate, will be reduced. Nigeria should move forward to embrace industrial production of this new source of food. This is because the wealth of a country depends on the production of goods and services through the co-ordinated use of the available supplies of human skills, capital and available raw materials.

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