
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

SOURCES OF WORLD FOOD PROTEIN AND THE NEW ZEALAND CONTRIBUTION

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SUMMARY

The production of protein from several sources is compared. The considerable variation that exists in the efficiency of protein production from plant and animal sources as well as between species of farm livestock is noted along with the problems encountered in the distribution and use of protein particularly in the underdeveloped world.

The forms of protein production that New Zealand is likely to develop as a contribution to world requirements are outlined.

WHILE there have been significant increases in the world's food production in recent years there is still a "protein gap" of the order of 30 million metric tonnes—equivalent to 70 million tonnes of skim milk powder (FAO, 1963). Protein in the diet is basic and the essential amino acids are required for normal growth (iso-leucine, leucine, lysine, methionine, phenylalanine, threonine, valine, tryptophane). Protein is also essential for mental development (Eichenwald and Fry, 1969; Ronchi, 1969). Children suffering from severe protein-calorie malnutrition show persistently low scores in adaptive behaviour during rehabilitation. Visual, haptic and kinesthetic factors are involved in most learning experiences which depend on the ability to integrate patterned formation. These factors are all affected by moderate but persistent degrees of malnutrition. Head circumference and brain size are reduced by a shortage of protein in the diet and low intelligence quotients result from the effect of such malnutrition. Thus sufficient protein is essential for social and intellectual development.

In reviewing protein sources and their comparative efficiencies it is useful to divide them into two categories, conventional and unconventional, the former being those that have been adopted by tradition. A short list of conventional protein sources includes meats, as livestock and poultry, fish, milk and crops subdivided into grains and legumes; these are all major protein sources. Unconventional sources include oil-seed protein meal, fish protein concentrate, dried algae, pasture protein, fungi and yeasts based on paraffin.

TABLE 1: BIOMASS DOUBLING TIME FOR SEVERAL SOURCES OF PROTEIN
(After Kosaric *et al.*, 1970)

Source	*Biomass Doubling Time*
Bacteria and yeast	20-120 min
Moulds and algae	2-6 hr
Green crops	1-2 wk
Chickens	2-4 wk
Pigs	4-6 wk
Cattle	1-2 mo

In comparing the efficiencies or activities of different sources of protein for man's use, one useful index is what may be called the "biomass doubling time" (Kosaric *et al.*, 1970). Table 1 sets out the doubling times for a number of protein sources.

Meat and milk are two sources of protein that may depend on feeds that could otherwise be utilized directly by man. The use of grain and crops for the production of meat and milk may thus be of dubious value in the future. On the other hand, there are many sources of protein that man cannot use directly but which can be used indirectly to produce food of high value. The use of grass, fish powder and yeast protein to feed cattle, chickens and pigs illustrates this point. It is, however, important to realize the enormous differences in protein yield that exist in this conversion process. Some examples are: Beef, 8%; pork, 17%; eggs, 23%; broilers, 26%; milk, 28% (Preston, 1968).

Broiler and milk production are thus seen to be at the top of the efficiency list in terms of percentage protein conversion from basic feedstuffs.

Land has been the traditional source of man's food with the exception of fish from the sea. While unconventional food sources will undoubtedly develop in the future, in the immediate task of feeding mankind we must look to the more effective use of land (Table 2).

If the cultural, aesthetic and economic factors are ignored, it is evident that grass and soyabean are outstanding performers as sources of adequate protein derived directly from the land. On the other hand, if the tastiness and versatility of the food are considered, milk derived from pasture and fish are very satisfactory sources of man's protein needs.

There are many potential unconventional sources of food for man. For comparative purposes two only will be discussed here, namely, algae and yeast.

TABLE 1: BIOMAS DOUBLING TIME FOR SEVERE SOURCES OF FEEDSTUFFS

Feedstuff	*Protein Production (kg/ha)*	*Essential Amino Acids (kg/ha)*
Maize	700	246
Soyabean	1,350	489
Grass	2,700	1,155
Meat, based on crops	290	111
Milk, based on crops	420	198
Meat, based on pasture	180	69
Milk, based on pasture	580	283
Fish (farmed)	650	—

The blue alga *Spirulina* is not exactly an unconventional food source. In the Republic of Chad it has been eaten for a long time. It grows in ponds rich in alkaline mineral salts, is harvested, formed into "pancakes" and dried in the sun. The protein content ranges between 60 and 68% and as a bonus it contains some vitamins. Experimental studies suggest that the annual production of *Spirulina* could be 40 to 45 tonnes/ha with a 25 tonne protein content (Gregory, 1969). With a biomass doubling time between 2 and 6 hr, together with simple harvesting and preparation techniques, clearly *Spirulina* has enormous potential as a source of food if it could be made attractive.

The production of *Spirulina* demonstrates the tremendous production potential of single cell protein sources. An even more spectacular achievement is the conversion of primitive nutrients into protein by yeast using petroleum as a source of energy (Kosaric *et al.*, 1970; Champagnat, 1967). While a 250 kg cow is capable of producing 0.25 kg of protein per day, 250 kg of yeast will produce 625 kg of protein per day—an incredible difference.

In overall conversion efficiency the yeast cell is quite remarkable. One kilogram of hydrocarbon will produce approximately 1 kg of dry biomass, half of which is protein. The substrate for the yeast, in this process, consists of the middle fractions from petroleum distillation. If we consider the annual crude oil production of the world, at the moment, to be 1,500 million tonnes, the middle fractions from this would yield an equivalent of yeast protein equal to the current protein gap. Yeast, based on hydrocarbon, is therefore a feedstuff with a high potential level

TABLE 3: COMPARATIVE COSTS OF SEVERAL FEEDSTUFFS (After Hutton, 1970; Kosaric *et al.*, 1970)

Feedstuff	*Cost per kg of Protein (c)*
Skim milk powder	51
Maize	35
Processed soyabean flour	40
Soyabean protein concentrate	97
Pasture protein	60
Hydrocarbon based yeast	20

of production but its use for this purpose competes with man's need for a versatile fuel.

In the light of the foregoing discussion it is interesting to examine the approximate costs of edible proteins from various sources. Table 3 gives a few comparisons (Hutton, 1970; Kosaric *et al.*, 1970). These figures can only be approximate. It is evident, for example, that protein based on pasture plants could well be produced much more cheaply when large-scale production is possible. It is also likely that single-cell proteins could be considerably cheaper than 20 cents/kg in the future. Unfortunately, cost is not a good indication of the likely performance in practice of a particular protein food. The failure of the FAO-based programmes to promote cheap, unconventional high-protein foodstuffs in South America illustrates this point (Gregory, 1969).

There are many criteria that form the basis for judging the overall efficiency of a particular protein food. Man is basically conservative in his food habits; thus conformity with a particular food convention is of primary importance for the rapid introduction of a new feedstuff. This militates against many unconventional materials and enormously reduces their effectiveness. Transport requirements are another important factor. The high production resulting from the "miracle rice" grown recently in Thailand has had disastrous consequences because of the inability of the country to transport the product from the production areas to the places where it will be consumed. Ideally, in an underdeveloped country production should be closely associated with the market. Simplicity of production is an important criterion. In underdeveloped countries the introduction of complex techniques requires a long educational period. Complex procedures are acceptable only if they are traditional but a simple procedure readily seen to be effective is not so difficult to introduce.

Another crucial criterion is capital. Despite the high efficiency of some capital intensive food production processes they are not likely to be helpful in a hungry country lacking capital resources. In tropical countries ease of preservation and storage of a foodstuff is often critical. Refrigeration is normally not available. This means storage at high ambient temperatures, often associated with high humidities. Thus the stability of a product could be a limiting factor in its effective use. Another consideration often overlooked is the biochemical suitability of a foodstuff in relation to man's requirements. The correct balance of amino acids has been referred to. The possibility of semi-toxic constituents that could have undesirable effects when consumed in quantity must always be considered. Finally, there is the question of long-term toxicity associated with impurities (Pokrovsky, 1970).

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SINGLE-CELL PROTEIN

The effects of consuming large amounts of algal- or yeast-based proteins are not yet fully understood. The consumption of yeast protein, in quantity, increases the uric acid level of the blood with the possibility of the formation of kidney stones. The possibility of long-term toxicity owing to the presence of unconventional metabolic products resulting from the hydrocarbon substrate also exists (Pokrovsky, 1970). If regarded as a food for animals, yeast protein would be more effectively produced at refineries placed nearer to the final centres of consumption.

PASTURE-PROTEIN CONCENTRATES

As an isolated industry it is difficult to see a place for this type of production in the near future. However, integrated with an existing meat or dairy industry with high-producing pastures it would appear to have a very substantial place in meeting the world protein shortage.

MAIZE AND SOYABEAN

These crops are undoubtedly low-cost sources of protein. Once products produced from them have lost the stigma of being a "poor man's food" they could have a tremendous future. While they may be produced efficiently in New Zealand, processing costs and transport may make their production non-competitive with that in other countries nearer their markets.

Fish

Fish foods have a long history and are highly acceptable. The high level of production of first-class protein on a per-hectare basis is unquestioned. While fish farming probably has a significant place in the future of the New Zealand food industry, it is unlikely to have a place in our contribution to the protein needs of the developing world. Fish protein concentrate is a splendid food with possibilities for addition to the human diet and has already been demonstrated to be valuable in feeding livestock and poultry. However, there are countries with lower labour costs that could produce this product more cheaply and nearer to the centres where it is required most urgently.

Poultry

This is another food accepted traditionally in many parts of the underdeveloped world. To be efficient, it must not compete with the foods that man can consume directly. Poultry production fits in nicely with the traditional mixed farming of many underdeveloped countries. It is hard, however, to see it as a New Zealand contribution to the world protein shortage as other countries can produce poultry more cheaply.

Meat

New Zealand can produce excellent meat very efficiently and there will always be a demand for this product. It is, however, a rich man's food. As the standard of living of the developing countries increases there will be an increase in demand for tasty steaks but this will be a minority demand and our contribution will be a small one compared with the world's protein needs. In a protein-hungry world the conversion of pasture into beef is extravagant but perhaps a significant contribution can be made with cheap sheep meats from New Zealand grasslands.

Milk

Milk production is the most effective method of converting pasture into protein suitable for man. Furthermore, the product has enormous versatility and widespread traditional acceptability. In helping to feed a hungry world the

New Zealand dairy cow has a place of pre-eminence but her nature will change in the future when the animal is considered in terms of protein production rather than milk fat.

For the optimum production of man's food and other needs from the land there is clearly a need for integration. Agriculture must learn to think "symbiotically". An example from the Indian dairy industry near Poona will illustrate the point. Here there is a large and efficient sugar industry producing as by-products molasses and bagasse. Urea is made cheaply in Bombay City not far away. Cattle fed on a mixture of molasses, bagasse and urea produce milk efficiently.

Another example that may well develop in the future is the use of pastures to produce milk and grass protein. The extracted grass residue with 50% of the protein left would still be a milk-producing diet for the dairy cow. The grass protein can be added to milk powder to form a special protein concentrate. In a similar way one could see the efficient production of soyabean used symbiotically with dairy production. Soya oil added to the low melting fractions of butterfat could produce a specially attractive cooking oil. The high melting fractions of the butterfat would make a butter suitable for use in the tropics. Some of the residue from the oil extraction process could be used as chicken feed; the balance could be converted into protein concentrate which again could be added to skim milk powder to give a special high protein food.

It is worth noting that skim milk and reduced-fat milk powder re-constituted and soured will produce curds which are traditionally consumed in many of the developing countries. Thus they fit in admirably with traditional food customs. Milk powders supplemented with grass protein or protein from soyabean would probably be equally effective.

Considering that a pasture farm is a method for collecting the free energy of sunlight and converting it into food, with modern pastures being the most effective converting agent, what is needed is a system that will automatically collect the pasture plant as it grows, particularly in areas where land is not suitable for high-intensity market gardening and the like. The second stage in the process is the breaking down of the cellulose of the roughage in a situation such that cheap nitrogen (say urea) may be added together with low cost carbohydrates, perhaps residues from another industry. This breakdown should take place in the form of a fermentation involving the production of a single cell protein complex that may then be transformed into proteins suitable for man's consumption by enzymic degradation of the protein material and its restructuring into first-class, animal-type protein. Ideally, the system would operate over a wide range of ambient temperatures and a fair variety of roughages. The most efficient system known, so far, capable of the full range of operations from roughage collection through single-cell protein production to the production of high quality protein for man's use, is the Friesian cow.

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