'QUORN' MYCOPROTEIN

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In the early 1960s people were concerned that, in the coming years, the traditional sources of protein food, such as beef cattle, pigs or poultry, would no longer be able to meet demand, even in the Western world. Food manufacturers therefore faced the challenge of identifying new sources of food protein and developing new protein-rich foods.

In 1964 the British food, milling and bakery group, Ranks Hovis McDougall PLC (RHM), decided to develop protein-rich foods for human consumption from the fungus *Fusarium graminearum*. The idea was to cultivate the fungus in a fermenter on a medium containing wheat starch as the carbon and energy source for growth, harvesting the biomass and modifying it as necessary to meet nutritional guidelines.

Initially the research concentrated on developing an alternative protein food from fungi. By the time the technology for growing and harvesting the fungus had been fully established, however, the shortage of protein (from traditional sources) that had been forecast had not materialised. Nevertheless the project turned out to be just as important, although for a different reason. The protein product which was developed ('myco-protein') is now being used in a range of foods to help satisfy current dietary needs. These are for diets giving a better nutritional balance, with a reduction in saturated fat and an increase in dietary fibre — precisely the combination of qualities that myco-protein provides.

In 1985, RHM and ICI jointly formed a company called Marlow Foods to produce various food products from fungal biomass and the trademark 'Quorn' was given to their myco-protein. In the same year J. Sainsbury launched the first retail product — a savoury pie — made with Quorn myco-protein. Now various food products made from Quorn myco-protein are sold by Tesco, Waitrose, British Home Stores, ASDA and Safeway.

Fig. 1. Scanning electron micrograph of A, Quorn myco-protein; B, cooked beef.

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MYCO-PROTEIN PRODUCTION

RHM chose a filamentous fungus rather than a bacterium or yeast for their project because mycelial biomass (unlike unicellular biomass) can be easily harvested from the broth in a fermenter, and because fungal hyphae look similar to the microfibrils of meat (Fig. 1) — it was just as important for any new protein food to be *visually* acceptable to a customer as to be *nutritionally* acceptable.

Like most of the fungi used by man, *Fusarium graminearum* was isolated from soil, in this case from a field in Marlow in Buckinghamshire (hence the name of the company). *F. graminearum* produces a mycelium made up of filaments (hyphae) which are 3-4μm in diameter and 1-2mm long. When grown in batch culture at 30°C the fungus can double its biomass every 2.5 hours, so the production of fungal protein is much more rapid than animal protein.

To produce myco-protein, *F. graminearum* is grown at 30°C on a medium containing glucose syrup, mineral salts and choline (longer hyphae are formed in the presence of choline). Glucose for the culture medium can be produced by hydrolysing corn, wheat, rice or potato starch, or from molasses.

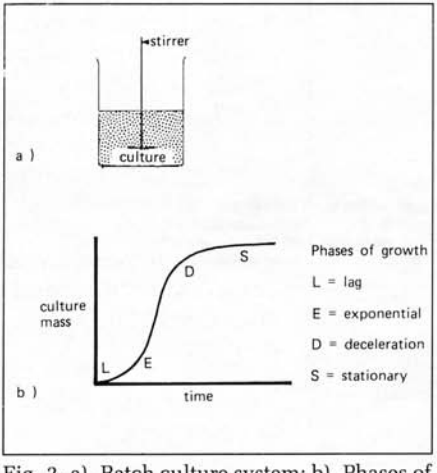

Fig. 2. a), Batch culture system; b), Phases of growth in batch culture system.

CONTINUOUS CULTURE

The simplest way of growing a fungus in submerged, liquid culture is to cultivate it in a batch culture system (Fig. 2a). In such systems, a small amount of the fungus is added to a set volume of medium. The culture is then incubated, and the fungal mass passes through lag, exponential, deceleration and stationary phases of growth (Fig. 2b). In batch culture systems, the conditions (nutrient concentration, pH, etc) under which the organism is cultivated change continuously throughout the period of growth.

To avoid the fluctuating conditions inherent in batch cultures, and to improve the overall productivity of the culture system. *F. graminearum* for myco-protein production is grown in a continuous culture system called a chemostat. In such systems, the culture is maintained in a perpetual exponential phase of growth by feeding it with fresh medium at a constant rate (F), while at the same time maintaining the volume (V) of the culture constant (Fig. 3). The dilution rate (D) of the culture (and hence the growth rate, μ, of the organism) is given by:

$$D \text{ (or } \mu) = \frac{F}{V}$$

Thus, the growth rate of an organism in continuous culture can be changed by altering the dilution rate. For myco-protein production, *F. graminearum* is grown at a dilution rate of 0.19 h^{1}, i.e. 0.19g of new fungal biomass is formed per gram of existing biomass per hour.

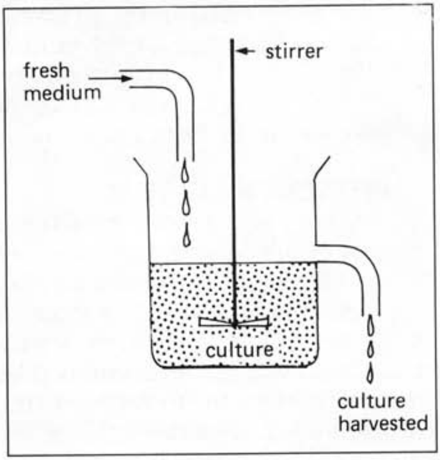

Fig. 3. Continuous culture system (e.g. chemostat).

AIR-LIFT FERMENTERS

Scientists at Marlow Foods are currently growing *F. graminearum* in a special type of fermenter known as an air-lift fermenter (see Fig. 4). This consists of a vertically-elongated closed loop about 40m high inside, in which the culture is circulated continuously. A circulated $40m^3$ volume of culture is maintained in the fermenter and is fed with glucose, minerals, ammonia (the nitrogen source for growth of the fungus) and compressed air (the growth of the fungus is aerobic). The volume of culture in the fermenter is maintained constant by removing culture at a rate identical to that at which the system is supplied with fresh medium.

Air-lift fermenters have no moving parts and use the difference in specific gravity of aerated culture in the 'riser' and the air-depleted culture in the 'downcomer' to obtain continuous circulation of the culture around the fermenter loop. In the production of myco-protein, a complete flow cycle is achieved in about 2 minutes. The use of this continuous culture system ensures that *F. graminearum* for myco-protein production is cultivated under environmental conditions which remain constant.

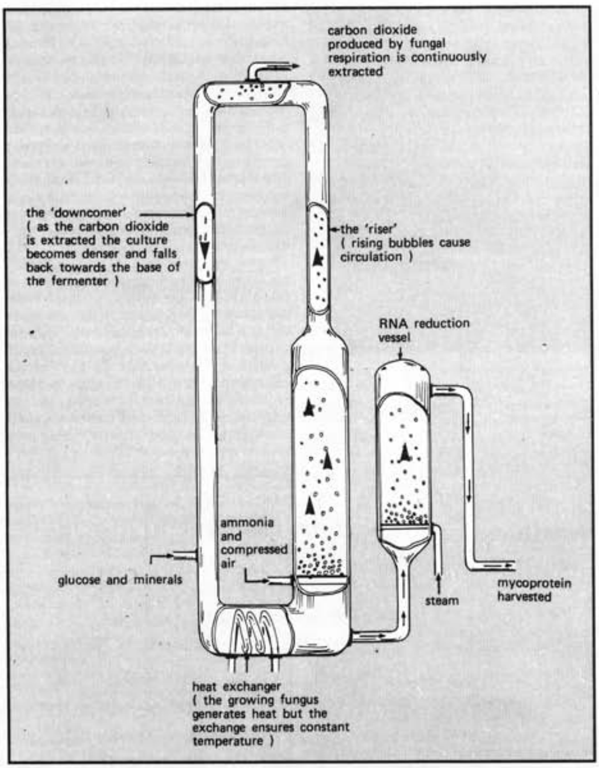

Fig. 4. Diagram of an air-lift fermenter

PROCESSING AND HARVESTING

Before Quorn myco-protein can be eaten by

	Cheddar cheese	Raw chicken	Raw lean beef	Stewing steak	Fresh cod	Raw beef sausage	Quorn myco-protein
Protein (g.100 g^{-1})	26.0	20.5	20.3	20.2	17.4	9.4	12.2
Dietary fibre (g.100 g^{-1})	0	0	0	0	0	0	5.1
Total fats (g.100 g^{-1})	33.5	4.3	4.6	10.6	0.7	24.1	2.9
Fats ratio (polyunsaturated fatty acids: saturated fatty acids)	0.2	0.5	0.1	0.1	2.2	0.1	2.5
Cholesterol (mg.100 g^{-1})	70	69	59	65	50	40	0
Energy (kJ 100 g^{-1})	1,697	506	514	736	318	1,250	334

Table 1. Quorn myco-protein compared with traditional animal protein sources.

man its RNA content must be reduced to meet World Health Organization (WHO) guidelines. This is done by heating the culture to 64° for 20-30 minutes which reduces the RNA-content of myco-protein to 1% of dry weight, well below the limit of 2% set by the WHO. The 64° treatment inactivates the fungal proteases (which stops these enzymes breaking down the proteins in the fungus) but allows the RNases (RNA-digesting enzymes) to break down ribosomal RNA. The small products of this RNA digestion diffuse through the hyphal walls into the culture broth and so are removed from the final product. Culture is harvested continuously from the fermenter. After its RNA content has been reduced, it is spread over a large moving filter through which most of the liquid is drawn off by vacuum, leaving behind a thin, pliable sheet of Quorn myco-protein which looks and tastes rather like raw pastry.

In 1980, after the production of a two-million word report describing the results of a ten-year programme of toxicological studies, RHM was given clearance by the Ministry of Agriculture, Fisheries and Food to market myco-protein for human consumption. During this testing programme, eleven species of animals (including pigs, cows and baboons) were fed myco-protein — in some cases for four generations — to see if there were any signs of toxicity either in the test animals or in their offspring. In addition, human trials were carried out by nutritionists at the Massachusetts Institute of Technology in the United States and by RHM in Britain. Myco-protein emerged unscathed from what were probably the most intensive tests made on any food prior to its appearance on the supermarket shelves.

RHM have developed new methods for transforming the myco-protein into appetising foods which can be eaten like meat and poultry (back cover). When harvested, myco-protein has a pale, buff colour and a mild flavour, so in most dishes appropriate colours and natural flavours are added.

Table 1 compares Quorn myco-protein with traditional protein sources. Quorn myco-protein has no animal fats, has a relatively high ratio of polyunsaturated fats to saturated fats, has a high-quality protein content comparable to milk protein, and contains dietary fibre. Its amino acid content is very close to that recommended by the United Nations Food and Agricultural Organization as ideal. Products made from Quorn myco-protein are therefore 'healthy', low-calorie foods. Why not try some?