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ANSWER BOOK

Industrial biotechnology and fermentation

Gene regulation, genomics and biotechnology · Unit B17

OCR A 6.2.1 · Edexcel A 4.14, 8.17 · Edexcel B 6.1 i, 6.1 ii, 6.1 iii, 6.1 v

15 questions · 51 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 IB-Q7

B1 they are cheap to feed, because many grow on waste from other industries such as whey, molasses or straw. **B1** production is independent of climate and season, because the environment is made inside the vessel; or there are no welfare objections; or the genome is small and easily altered, so a strain is quickly improved. [2]

A2 IB-Q15

A1 the fungus Fusarium venenatum. **A1** glucose syrup as the carbon source and ammonia as the nitrogen source. [2]

SECTION B · Standard, 3 to 5 marks

B1 IB-Q1

B1 a dense culture respires hard and respiration releases heat, so water circulating through the cooling jacket carries that heat away and holds the optimum temperature. **B1** metabolism produces carbon dioxide and organic acids, so a pH probe monitors the broth and acid or alkali is metered in to hold the optimum pH. **B1** an aerobic culture uses oxygen faster than it dissolves, so sterile air is forced in through the sparger near the bottom of the vessel. **B1** the impeller breaks up the rising bubbles and keeps organisms, nutrients, heat and oxygen evenly mixed, so no part of the tank becomes a stagnant corner running anaerobic. [4]

B2 IB-Q2

B1 batch culture is closed, with nothing added after inoculation, whereas continuous culture is open, with sterile medium flowing in and culture flowing out at matching rates. **B1** a batch culture passes through the whole curve and is harvested once, usually early in the stationary phase, whereas a continuous culture is held permanently in the exponential phase and never reaches stationary, because nutrients never run out and wastes never accumulate. **B1** batch production is slower overall, because the vessel spends time in lag phase, harvesting and cleaning, whereas a continuous vessel is always at peak output and runs for weeks. **B1** contamination costs a batch process one run, whereas it costs a continuous process a long production run. [4]

B3 IB-Q3

B1 the antibiotic is a secondary metabolite, made only as growth slows and the culture enters the stationary phase. **B1** it must therefore be made in batch culture, because a continuous culture is held in the exponential phase and never experiences the conditions that switch production on, so it would grow bacteria and make almost no antibiotic. **B1** the biomass is the product of growth itself, a primary product that accumulates fastest while the culture is growing exponentially. **B1** it therefore suits continuous culture, with cells drawn off as fast as they are replaced, so the vessel stays at peak output instead of losing time to harvesting and cleaning. [4]

B4 IB-Q4

B1 in favour: mycoprotein is produced in days in a small building all year round, on cheap substrates, and uses far less land and water per kilogram of protein than livestock, with no animal reared or slaughtered. **B1** in favour: the hyphae of **Fusarium** venenatum give a fibrous texture close enough to muscle to stand in for meat, and the product is high in protein and fibre, low in fat and free of cholesterol. **B1** against: the product has little taste of its own so flavour and colour must be manufactured into it, the cells are rich in nucleic acid whose breakdown product uric acid can cause gout so this must be reduced during processing, and some people are unwilling to eat a fungus grown on industrial glucose. **B1** a judgement supported by those points, for example that the nutritional and environmental case is strong provided the nucleic acid content is reduced and the food is labelled honestly, while accepting that the sterile, precisely controlled plant is expensive to build and a contaminated batch is a food-safety failure. [4]

B5 IB-Q8

B1 the fungus is grown in continuous culture on glucose syrup, with ammonia supplied as the nitrogen source. **B1** the fungal hyphae are harvested continuously as the culture grows. **B1** the harvested biomass is heat-treated, partly to reduce its nucleic acid content. **B1** it is then pressed into a textured food product, the fibrous hyphae giving it a texture close enough to muscle to stand in for meat. [4]

B6 IB-Q9

B1 a lag phase, during which the population adjusts to the new medium and synthesises the enzymes it requires, so numbers barely rise. **B1** an exponential, or log, phase, during which nothing yet limits growth and the population doubles at a constant rate. **B1** a stationary phase, when a nutrient runs short or a waste product accumulates, so the rate of division comes to balance the rate of death and numbers level off. **B1** a death phase, when deaths exceed divisions and the population falls. [4]

B7 IB-Q10

M1 dilution rate = flow rate ÷ culture volume, rearranged to flow rate = dilution rate × volume. **A1** 0.15 × 8000 = 1200 dm^3 per hour. **M1** time for one working volume to pass through = volume ÷ flow rate. **A1** 8000 ÷ 1200 = 6.7 hours, which is about 6 hours 40 minutes. [4]

B8 IB-Q11

B1 for: filtering the incoming air does remove airborne bacteria and spores from that one contamination route, so some protection against contamination would remain. **B1** against: the growth medium itself, and the vessel and pipework, are further routes by which contaminating organisms can enter, and skipping medium sterilisation leaves those routes open. **B1** against: a contaminating organism can compete for the substrate, out-grow or degrade the product, and in a food or medicine renders the whole batch unsellable, so the saving from skipping one step could easily be outweighed by the cost of losing an entire batch. **B1** judgement: the proposal is not defensible as it stands, since the saving is small and the failure mode is a complete batch loss, though validating a shortened rather than an eliminated sterilisation cycle could be worth investigating. [4]

B9 IB-Q5

B1 a contaminating organism competes for the substrate and may out-grow the production strain or destroy the product, and in a food or a medicine it renders the whole batch unsellable. **B1** the vessel is sterilised with pressurised steam between runs and the medium is sterilised before it enters. **B1** the incoming air is passed through filters fine enough to remove bacteria and spores, and every other inlet is treated as a contamination route and sterilised. [3]

B10 IB-Q6

M1 the number of divisions is the time divided by the doubling time, so 240 ÷ 20 = 12. **M1** the number present is the starting number multiplied by 2 raised to the number of divisions, so $5.0 \times 10^4 \times 2^{12}$. **A1** 2^{12} is 4096, giving 2.05×10^8 bacteria. [3]

B11 IB-Q12

B1 microbial cells are proportionately much richer in nucleic acid than the cells of a plant or animal food source, because they are small and each one holds a full genome relative to its size. **B1** nucleic acid consumed in the diet is broken down, and one breakdown product is uric acid. **B1** a high intake of uric acid can cause gout, so the nucleic acid content of the harvested biomass must be lowered before it is sold as food. [3]

B12 IB-Q13

B1 a bacterium such as Escherichia coli can double its numbers in about twenty minutes given warmth and nutrients, whereas a fungus doubles over hours and a cow doubles its numbers over years. **B1** industrial biotechnology exploits this difference by culturing microorganisms rather than farming plants or animals, since a much larger yield can be obtained from a given starting culture in a much shorter time. **B1** generation time is one of several distinct reasons for using microorganisms, working alongside low-cost substrates, conditions set inside the vessel rather than by season, no animal-welfare objections and ease of genetic modification, rather than being the whole explanation on its own. [3]

B13 IB-Q14

B1 each probe continuously measures a condition, temperature or pH, so that a departure from the optimum set point is detected. **B1** the fermenter's control system responds by correcting the departure, for example running more coolant through the jacket if the temperature rises, or metering in alkali if the pH falls. **B1** the correction acts to return the condition towards its original set point rather than push it further away, which is what makes the control negative feedback. [3]

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