SQA Advanced Unit specification

General information

Unit title: Fermentation Engineering (SCQF level 7)

Unit code: HV02 47

Superclass: RH

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Source: Scottish Qualifications Authority

Version: 01

Unit purpose

This Unit is designed to enable learners to understand key aspects of fermentation engineering including bioreactor equipment and its applications in a range of industries, which can include beverage, chemicals, pharmaceuticals and industrial biotechnology. The Unit is suitable for learners studying at SQA Advanced Certificate/Diploma level, and will provide the necessary underpinning knowledge and skills to enable progression to further study of fundamental chemistry at SQA Advanced Diploma level or to seek employment in science and engineering based industries.

Outcomes

On successful completion of the Unit the candidate will be able to:

1 Explain the operation of major types of bioreactor equipment.
2 Select equipment and procedures for fermentation processes.

Credit points and level

1 SQA Credit at SCQF level 7: (8 SCQF credit points at SCQF level 7)

Recommended entry to the Unit

Entry is at the discretion of the centre, however it is recommended that learners should have prior experience of maths at SCQF level 6.

Core Skills

Achievement of this Unit gives automatic certification of the following Core Skills component:

Complete Core Skill	None
Core Skill component	Using Number at SCQF level 6

Context for delivery

If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

The Assessment Support Pack (ASP) for this Unit provides assessment and marking guidelines that exemplify the national standard for achievement. It is a valid, reliable and practicable assessment. Centres wishing to develop their own assessments should refer to the ASP to ensure a comparable standard. A list of existing ASPs is available to download from SQA's website **(http://www.sqa.org.uk/sqa/46233.2769.html)**.

Equality and inclusion

This Unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**.

SQA Advanced Unit specification: Statement of standards

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Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Explain the operation of major types of bioreactor equipment.

Knowledge and/or Skills

- Classifications of bioreactor
- Methods of operation
- Sterilisation, inoculation and aseptic material transfer procedures
- Sensors and control equipment for bioreactor operations
- Downstream processing
- Product recovery operations

Outcome 2

Select equipment and procedures for fermentation processes.

Knowledge and/or Skills

- Mathematical modelling of biological growth kinetics in batch fermentation process
- Mathematical modelling of biological growth kinetics in fed-batch fermentation process
- Mathematical modelling of biological growth kinetics in continuous fermentation process
- Mathematical modelling of oxygen transfer rates in aerobic fermentation processes
- Mathematical modelling of death rates of cells and spores in thermal sterilisation processes
- Mathematical modelling of the removal rates of cells and spores in filtration sterilisation processes

Evidence Requirements for this Unit

Learners will need to provide evidence to demonstrate their Knowledge and/or Skills across all Outcomes.

Written and/or oral recorded evidence for Outcomes 1and 2 should be assessed using a single holistic closed-book assessment under supervised conditions. It is recommended that the assessment be completed within 60 minutes.

Outcome 1

The assessment will cover a minimum of four of the six Knowledge and/or Skills items. Candidates will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternate (resit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- describe the design of at least two classifications of bioreactor equipment from. Static batch and fed-batch fermentations, Stirred tank batch and fed-batch fermentations for production of yeast extracts or antibiotics, Agricultural fermentations in the ethanol fuel industry, Stirred tank and airlift bioreactors, Hollow fibre bioreactors for the culture of anchored cells.
- explain the method of operation of at least two classifications of bioreactor equipment from. Static batch and fed-batch fermentations, Stirred tank batch and fed-batch fermentations, Stirred tank batch and fed-batch fermentations for production of yeast extracts or antibiotics, Agricultural fermentations in the ethanol fuel industry, Stirred tank and airlift bioreactors, Hollow fibre bioreactors for the culture of anchored cells.
- describe procedures for the sterilisation, inoculation and aseptic sampling of bioreactors at least two procedures from autoclave, thermal sterilisation of growth media in batch and continuous fermentations, Sterilisation by filtration, In-situ sterilisation using steam and chemical agents. The explanation must also include the addition and removal of materials under aseptic conditions and approved codes of practice for sterilisation and containment.
- explain the use of sensors and control equipment in the measurement and control of temperature, pH, oxygen concentration and other process variables during bioreactor operations.
- explain downstream processing. The explanation must include two processes.
- describe product recovery operations in the fermentation industries. The explanation must include two operations from solvent extraction, centrifugation, vacuum filtration, ultrafiltration; and HPLC and affinity chromatography.

Outcome 2

The assessment will cover a minimum of three of the six Knowledge and/or Skills items. Candidates will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternate (resit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- perform at least two calculations involving mathematical modelling of biological growth kinetics in batch fermentation process.
- perform at least two calculations involving mathematical modelling of biological growth kinetics in fed-batch fermentation process.
- perform at least two calculations involving mathematical modelling of biological growth kinetics in continuous fermentation process.
- perform, at least two, calculations involving mathematical modelling of oxygen transfer rates inaerobic fermentation processes.
- perform at least two calculations involving mathematical modelling of death rates of cells and spores in thermal sterilisation processes.
- perform at least two calculations involving mathematical modelling of the removal rates of cells and spores in filtration sterilisation processes.

For Outcome 2 there is the need to use complex mathematical formula, it is envisaged that learners would not have to memorise these but have access to suitable formula sheet. Thus testing their understanding of applying the correct formula rather than their ability to remember them.

SQA Advanced Unit Support Notes

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Unit Support Notes are offered as guidance and are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit may form part of a group award or be completed as a free-standing Unit. It is designed to enable learners to understand key aspects of fermentation engineering and its applications in a range of industries.

Outcome 1

The range of manufacturing processes in which the growth of biological cells is the primary activity and the range of bioreactor equipment in which these processes are carried out:

- Static batch and fed-batch fermentations of fruits and grains in the alcoholic beverage industries
- Stirred tank batch and fed-batch fermentations for the production of yeast extracts
- Stirred tank batch and fed-batch fermentations for the production of antibiotics
- Agricultural fermentations in the ethanol fuel industry
- Stirred tank and airlift bioreactors for plant and animal cell suspension cultures
- Hollow fibre bioreactors for the culture of anchored cells

Procedures for the sterilisation of growth media and bioreactor equipment, exclusion of contamination and containment of hazardous organisms:

- The autoclave for the sterilisation of portable equipment
- Thermal sterilisation of growth media in batch and continuous fermentations
- Sterilisation by filtration
- In-situ sterilisation of bioreactor equipment using steam and chemical agents
- Addition and removal of materials under aseptic conditions
- Approved codes of practice for sterilisation and containment

Measurement and control of temperature, pH, oxygen concentration and other variables during bioreactor operations:

- Temperature control using water jackets and cooling coils
- The autoclavable pH electrode and oxygen sensor
- In-situ cell counting, sample counting and foam control

Downstream processing and product recovery operations in the fermentation industries:

- Solvent extraction and centrifugation
- Vacuum filtration and ultrafiltration
- HPLC and affinity chromatography

Outcome 2

Mathematical modelling of biological growth kinetics in batch, fed-batch and continuous fermentation processes:

- Specific growth rate, doubling time, substrate uptake rate, product formation rate, yield coefficients, maintenance coefficients, the Monod model and other models
- Mass balances in batch, fed-batch and continuous fermentations
- Effects of temperature and pH changes, process optimisation

Mathematical modelling of oxygen transfer rates in aerobic fermentation processes:

- The two-film theory of mass transfer across the gas-liquid boundary
- Bubble behaviour and mass transfer rates in the airlift bioreactor and the stirred tank bioreactor
- The measurement of oxygen transfer rates in operating bioreactors

Mathematical modelling of death rates of cells and spores in thermal sterilisation procedures and the removal rates of cells and spores in filtration sterilisation procedures:

- First order kinetics in thermal sterilisation processes
- Experimental evidence for the first order model
- The Arrhenius equation, the Del factor and holding time calculations
- Kinetics of cell and spore removal in filtration sterilisation processes

Guidance on approaches to delivery of this Unit

The suggested order for delivery of this Unit is Outcome 1 then Outcome 2.

It is envisaged that the content of this Unit could be delivered standalone, or embedded within other Units of the SQA Advanced award. Centres may choose to integrate selected Outcomes within other Units.

It is envisaged that delivery of Outcome 1 would commence with an introduction to the manufacturing process in which the growth of biological cells is the primary activity and the range of bioreactor equipment in which the processes are carried out. These will include the use of static batch and fed batch fermentation of:

- fruits and grains in the drink industries.
- the production yeast extracts.
- the production of antibiotics.

Bioreactor equipment used to produce ethanol fuel from agricultural sources. Bioreactors used in the production of plant and animal cell suspensions and hollow fibre reactors for the culture of anchored cells.

Learners should also be taught about the need for sterilisation of bioreactors, the need to contain hazardous organisms and how to exclude contamination. This should include the use of the autoclave for sterilisation of portable equipment, thermal sterilisation, sterilisation by filtration. The use of in-situ sterilisation which could be the use of steam or chemicals. How to add and remove materials under aseptic conditions. Learners should be taught current approved codes of practice for sterilisation and containment.

Learners should be aware of control systems in place to ensure process parameters are kept within the required tolerances. This could be pH, oxygen level, temperature, etc. Learners should have an understanding of measurement equipment that can be used to control these processes.

Downstream process and product recovery should then be taught these will include:

- Solvent extraction and centrifugation
- Vacuum filtration and ultrafiltration
- HPLC and affinity chromatography.

For Outcome 2 there is the need to use complex mathematical formula, it is envisaged that learners would not have to memorise these but have access to suitable formula sheet. Thus testing their understanding of applying the correct formula rather than their ability to remember them.

The mathematical modelling uses kinetics to model several processes which may include growth kinetics of batch, fed batch and continuous fermentation, mathematical modelling of oxygen transfer rates in aerobic fermentation process. areas to cover for the modelling are detailed in the content and context guidelines.

Areas that could be covered in the mathematical modelling section could be:

- estimate vessel volume, nutrient requirements, service flowrates and product formation rate in batch fermentation and continuous fermentation processes using mathematical models chosen from specific growth rate, doubling time, substrate uptake rate, product formation rate, yield coefficients, maintenance coefficients, the Monod model and other models. Effects of temperature and Ph changes, process optimisation.
- estimate aeration requirements in aerobic fermentation processes using mathematical models. The estimation must include the two-film theory of mass transfer across the gas-liquid boundary, bubble behaviour and mass transfer rates in the airlift bioreactor and the stirred tank bioreactor, and the measurement of oxygen transfer rates in operating bioreactors.
- select appropriate sterilisation conditions for growth media and bioreactor equipment using mathematical modelling of death rates of cells and spores in thermal sterilisation procedures, and the removal rates of cells and spores in filtration sterilisation procedures: first order kinetics, Arrenhius equation, holding time calculations.

Guidance on approaches to assessment of this Unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

Outcomes 1 and 2 could be assessed by a single holistic closed-book question and answer assessment with an appropriate cut-off score. Assessment should be carried out in supervised conditions, and it is recommended to last for 60 minutes.

Opportunities for e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at **www.sqa.org.uk/e-assessment**.

Opportunities for developing Core and other essential skills

Although there is no automatic certification of Core Skills in the Unit, you will have opportunities to develop the Core Skills of *Numeracy* and *Problem Solving* at SCQF level 6.

There will be opportunities to develop Core Skills throughout this Unit, examples of which are as follows:

Numeracy — Using Number at SCQF level 6

Learners will be required to decide on the steps and operations to solve complex problems, and carry out sustained and complex calculations throughout the Unit.

Problem Solving — Critical Thinking at SCQF level 6

Learners will develop their critical thinking skills by solving problems, comparing processes and selecting formula.

This Unit has the Using Number component of Numeracy embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show they have achieved Using Number at SCQF level 6.

History of changes to Unit

Version	Description of change	Date

FURTHER INFORMATION: Call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

General information for learners

Unit title: Fermentation Engineering (SCQF level 7)

This section will help you decide whether this is the Unit for you by explaining what the Unit is about, what you should know or be able to do before you start, what you will need to do during the Unit and opportunities for further learning and employment.

This is a 1 credit Unit at SCQF level 7, which is suitable for learners studying at SQA Advanced Certificate/Diploma level. Before progressing to this Unit it would be beneficial to have completed study of Mathematics at SCQF level 6 (Higher level) where you will have learned underpinning aspects of chemistry and developed your mathematical skills. There is a strong emphasis in the Unit on the applications of the physical chemistry taught and in particular industrial applications.

On completion of the Unit you should be able to:

1 Explain the operation of major types of bioreactor equipment.
2 Select equipment and procedures for fermentation processes.

The Unit is designed to provide you with an overview of fermentation processes in the beverage, chemicals and pharmaceutical industries, knowledge of the equipment in use, and some technical details of its operation. The level of detail should be useful to you if you are employed or expecting to be employed as a process operator in industries using fermentation processes. In addition, the Unit is intended to help you, as part of your SQA Advanced studies, gain entrance to degree studies in Chemical Engineering at second or third year level.

The Unit has two main areas:

- types of bioreactor and methods of operation
- technical details of equipment and process design

On completion of the Unit, you should be able to:

- describe the manufacture of a range of products obtained from fermentation processes and the range of equipment in use.
- perform calculations to estimate the dimensions and operational details of bioreactor equipment.

To complete the Unit successfully, you must provide satisfactory responses to a number of questions. These questions will require descriptions and explanations of types of bioreactor equipment and calculations to estimate some aspect of equipment performance. There may be one single assessment period lasting approximately one hour, under supervised conditions.

Although there is no automatic certification of Core Skills in the Unit, you will have opportunities to develop Core Skills in *Numeracy*, and *Problem Solving* at SCQF level 6. Throughout the Unit, you will perform calculations, manage formulae and perform equations that will help develop the Core Skill of *Numeracy*, and the *Problem Solving* component Critical Thinking at SCQF level 6.