Institute of Brewing & Distilling

# The Diploma in Brewing (Dipl. Distil.)

# Examination Syllabus

**(Valid from 2010)**

## THE INSTITUTE OF BREWING AND DISTILLING

## THE DIPLOMA IN DISTILLING QUALIFICATION

### BACKGROUND

The Institute of Brewing & Distilling (IBD) is a members' organisation dedicated to the education and training needs of brewers and distillers and those in related industries. It does this by offering a range of internationally recognised qualifications and the training to support them, either through direct instruction or by distance learning.

The Mission Statement of the Institute of Brewing & Distilling (IBD) is "To be recognized as the world's leading members organization for the advancement of education and training in the science and technology of brewing, distilling and related industries". Consistent with the achievement of this objective is the requirement for the means of assessing the levels of knowledge, understanding and competence of those educated and trained. The method of assessment is by examination and the Institute operates three levels of examination.

The Distilling Qualifications have been offered since 1994 and there are three levels. The first level is the Fundamentals of Distilling – a new qualification aimed at those not directly involved in the production process, but wishing to learn more about the fundamentals of distilling.

The second level is the General Certificate in Distilling, (GCD), offered to candidates since 2001. This examination is a measure of the basic knowledge, both theoretical and practical underpinning distilling. It is aimed at team members, team leaders and technicians. It can be the first step on the ladder of professional development, leading to the Diploma in Distilling or it may be an end in itself. It is also a useful qualification for other distillery personnel, for example in HR, finance, logistics and engineering, who will benefit from a better understanding of distilling operations. The syllabus covers the three main substrates used in distilling: cereals, molasses and grape and therefore has international appeal.

The third and, currently, top level of distilling qualifications is the Diploma in Distilling. This syllabus has been written to expand the distilling qualification to cover the main substrates for potable spirits: cereals, molasses and grapes, and the qualification requires an understanding of all three. The Diploma provides team leaders, operational managers and technicians with the theoretical knowledge that enables them to perform better, improving the basis on which decisions are taken. Although the examination has been offered since 1994, it

has now been given a truly international perspective and covers the basic underlying theory for the production of most potable spirits.

## ADVICE TO CANDIDATES

The syllabus of each Module is divided into units, which cover a topic area. Each unit is then sub-divided into elements and there may be several elements covering the science and technology associated with this unit. Each element then has text associated with it to describe the level of detail required. Thus the syllabus is presented in considerable detail and candidates are advised to use it as a revision tool and to tick off each element as part of their examination preparation.

Virtually the whole syllabus is covered by a concise reading list available separately from The Institute of Brewing & Distilling.

Unless otherwise stated, candidates are expected to achieve a detailed understanding of a topic; consistent with the objectives of the examination. The adjectives “basic” and “outline” are used when a lesser depth of knowledge is required.

“The basic concept of …” means the ability to explain all the major principles, functions or purpose relevant to the topic, without the need to describe its intricacies.

“An outline of …” means a summary description of the scientific principles, plant or process concerned.

Where there are references in the syllabus to chemical compounds, candidates are expected to know the scientific principles and significance of their role in the process. Knowledge of complex formulae and advanced chemistry is not required.

Where there are references in the syllabus to mathematical equations & simple calculations, candidates are expected to use straightforward mathematics in the specified applications relevant to distillery operations. Commitment to memory of complex equations and formulae is not required. However, candidates are expected to know the basic formulae, which govern key scientific principles.

Candidates are strongly advised to acquire an experienced Mentor for their period of study, capable of providing the initial advice on minimum scientific comprehension (as indicated in the above definitions), followed by general direction, support and assessment of progress through a Module.

## EXAMINATION DETAILS

Qualification to sit the Diploma in Distilling is Membership of the Institute of Brewing & Distilling.

The three Modules may be sat in any order, and there are no time limits for sitting one or all of the Modular Examinations.

## REGISTRATION FOR EXAMINATION

The Diploma in Distilling examination takes place in June of each year.

Candidates must register with the Institute by 1st December of the previous year. Registration fees and any special conditions are published regularly in the Institute's publications.

## ISSUE OF CERTIFICATED QUALIFICATIONS

*The Institute of Brewing & Distilling will separately certificate each Module, with success in all three Module Examinations qualifying for the use of post nominals, "Dipl.Distil." Successful candidates will receive a Diploma in Brewing certificate.*

## CONTACT FOR ENQUIRIES

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# DIPLOMA IN DISTILLING EXAMINATION SYLLABUS

**MODULE 3 PROCESS TECHNOLOGY** **Page**

# Institute of Brewing and Distilling

# Diploma in Distilling Qualification

## Module 1: Preparation of Fermentable Extract

### 1A: Cereal wort
### 1B: Molasses wort
### 1C: Grapes must

## Module 2: Fermentation, Distillation & Maturation

## Module 3: Process Technology

Each module is examined by a 3-hour examination:
Module 1: Multiple choice paper, 1 hour, covering an overview of all three substrates - cereal, molasses and grape - for potable distilled spirit production.
Then a 2-hour essay paper, answering 4 questions out of 6 from one only of the syllabii 1A, 1B or 1C; a choice of cereal, molasses or grape substrates.

Module 2: 3-hour essay paper, answering 6 questions out of 8 from a single syllabus.

Module 3: 3-hour essay paper, answering 6 questions out of 8 from a single syllabus.

# MODULE 1

**Contents: Module 1A Raw Materials and Preparation of Cereal Wort**
**Module 1B Preparation of Molasses Wort**
**Module 1C Preparation of Grape Must**

## Module 1A: RAW MATERIALS AND PREPARATION OF CEREAL WORT

### Unit 1A.1 Barley

1A.1.1 The Physiology and Morphology of Barley
- 1A.1.1.1. Barley plant development
- 1A.1.1.2. Barley fertilization
- 1A.1.1.3. Two- and Six-rowed barley
- 1A.1.1.4. Barley grain development post-fertilization
- 1A.1.1.5. Structure of the barley grain
- 1A.1.1.6. Composition of cereal grains

1A.1.2 Environmental and Agronomic Factors influencing the Growth of Barley
- 1A.1.2.1. Climate
- 1A.1.2.2. Soil
- 1A.1.2.3. Soil nutrients
- 1A.1.2.4. Crop competitors – weeds, pests and diseases

1A.1.3 Harvesting and Storage of Barley
- 1A.1.3.1. Moisture at harvesting
- 1A.1.3.2. Barley drying
- 1A.1.3.3. Barley storage

1A.1.4 Dormancy
- 1A.1.4.1. Reasons for dormancy
- 1A.1.4.2. Mechanism of dormancy
- 1A.1.4.3. Barrier effects of seed coats
- 1A.1.4.4. Effects of light on dormancy
- 1A.1.4.5. Presence and absence of inhibitors
- 1A.1.4.6. Shifts in oxidative pathways
- 1A.1.4.7. Genetic controls
- 1A.1.4.8. Overcoming dormancy
- 1A.1.4.9. Types of dormancy

1A.1.5 Water Sensitivity

1A.1.6 Principles of barley breeding and selection for malting
- 1A.1.6.1. Traditional barley breeding
- 1A.1.6.2. Mutations
- 1A.1.6.3. Acceptance of new barley varieties
- 1A.1.6.4. Breeding assisted by molecular biology techniques

**Unit 1A.2 Cereals and Enzymes used in Processing Cereals for Grain Whisky and Grain Neutral Spirit**

1A.2.1 General Specifications

1A.2.2 Maize

1A.2.3 Wheat

1A.2.4 Rye

1A.2.5 Barley

1A.2.6 Enzymes for GNS Production and Non – Scotch Whisky

**Unit 1A.3 Malting**

1A.3.1 Evaluation of Barley for Malting

1A.3.1.1. Characteristics of malting barley

- Variety
- Germinability
- Nitrogen (Protein) content
- Grain size
- Dormancy
- Endosperm structure and cell wall composition
- Pre-germination
- Husk content

1A.3.1.2. Methods for assessing the quality of barley

- Micro-malting
- Germinative energy
- Water sensitivity test
- Germinative capacity
- Tetrazolium viability test
- Extract potential
- Regularity principle (Bishop's equation)

1A.3.2 Barley Intake and Preparation for Malting

1A.3.2.1. Barley intake, sampling and testing

1A.3.2.2. Preparation of barley for malting

- Barley separation
- Barley grading

1A.3.3 The Malting Process – Conversion of Barley into Malt

1A.3.3.1. Overview of the three phases of malting

1A.3.3.2. The Malting Process – Steeping and Grain Hydration

1A.3.3.2.1. Steeping technology

1A.3.3.2.2. Steeping systems and air rests

- Systems for setting up steep regimes
- Multiple steeping and evenness of germination & modification
- Initiation of germination
- Air rest temperature
- Steeping cycles
- Monitoring of steeping
- After steeping

1A.3.3.2.3. Factors influencing water uptake

- Temperature
- Grain size
- Protein content
- Grain viability
- Variety and crop year

1A.3.3.3. The Malting Process – Germination and Endosperm Modification

- Gibberellin synthesis
- Enzymes and substrates involved in endosperm modification
- Cell wall β-glucans and pentosans
- Endosperm protein and proteolysis
- Starch granules and granule modification

1A.3.3.3.1. Germination technology

- Specifications for germination vessels
- Turning the grain

1A.3.3.3.2. Germination control parameters

- Moisture control
- Effect of moisture on modification
- Effects of temperature on germination
- Effects of temperature on enzyme development
- Effects of temperature on rate of modification
- Air-on and air-off temperatures
- Control of temperature
- Effects of high summer temperatures

1A.3.3.3.3. Physiological and Biochemical changes which influence malting loss

- α-Amylase
- β-Amylase
- Proteolysis
- Solubilization and breakdown of β-glucans

1A.3.3.3.4. Control of malting loss

1A.3.3.4. The Malting Process – Kilning

1A.3.3.4.1. Purpose of kilning

1A.3.3.4.2. The physical process of kilning

- Free drying
- Forced drying
- Peated malt and peating technology

1A.3.3.4.3. Kiln design and technology

- Energy consumption
- Modern kilning technology
- Indirect and direct kiln firing

1A.3.3.4.4. Kilning biochemistry

- Enzyme denaturation
- Nitrosodimethylamine (NDMA)

**Unit 1A.4 Malt Processing in the Distillery**

1A.4.1 Malt Performance – Requirements of Good Quality Malt

- General quality parameters (malt distilling and high diastase malts)
- Malt specifications
- Effect of barley variety on malt quality

1A.4.2 Key Malt Analytical Parameters

- Moisture
- Friability and homogeneity
- Soluble extract
- Fermentability
- Fermentable extract
- Predicted spirit yield (PSY)
- Total soluble nitrogen
- Malt enzyme levels
-

1A.4.3 Malt Delivery and Handling

1A.4.3.1. Malt Delivery Procedures

1A.4.3.2. Malt Intake

- Sampling
- Storage
- Screening/Grading and Dressing

1A.4.3.3. Safety Concerns (Dust)

1A.4.4 Milling

1A.4.4.1. Purpose of Milling
- Mill types

1A.4.4.2. Comminution

1A.4.4.3. Influence of friability on Milling

1A.4.4.4. Milling operations
- Compression and shear
- Mechanism of grain destruction

1A.4.4.5. Grist evaluation
- Grist analyses

1A.4.4.6. Milling safety

**Unit 1A.5 Mashing in Malt Whisky Distilleries**

1A.5.1 Mashing Procedures

1A.5.2 The Principles an Purpose of Mashing

1A.5.3 Calculation of Mash Tun Extract in a Malt Distillery

1A.5.4 The Principles and Purpose of Mash Separation
- Traditional Mash Tun
- Semi – Lauter and Lauter Tun
- Mash Filter

1A.5.5 Spent Grain Discharge

1A.5.6 Prevention of Microbial Contamination

1A.5.7 Preservation of Enzyme Activity in Wort

1A.5.8 Wort Properties

1A.5.9 Wort Cooling and Aeration

**Unit 1A.6 Cooking and Mashing in Grain Distilleries**

1A.6.1 Preparation of Wort from a Mash Bill high in Unmalted Cereal, with a small proportion of Malted Barley

1A.6.2 Preparation of Wort from 100% Unmalted Cereal and Microbial Enzymes

1A.6.2.1. The Selection of Exogenous Enzymes
- Alpha-Amylase
- Amyloglucosidase (glucoamylase)
- Pullulanase (debranching enzyme or limit dextrinase in malt)
- Protease
- Other activities

1A.6.3 Cereal Cooking

- Batch cooking
- Continuous cooking
- Cooling after cooking

**Unit 1A.7 Water**

1A.7.1 Basic Quality Requirements of Water

1A.7.2 Production Requirements of Water n Distilleries

1A.7.3 Water Sourcing

- Borehole water
- Surface water

1A.7.4 The Principal Characteristics and Requirements of a Distillery Water Supply

- Production (Mashing) water
- Product water
- Process water
- Service water
  - Boiler water
  - Cooling tower water
  - Cooling towers – *Legionella* risk
  - General cleaning water

1A.7.5 Water Usage Ratios, Conservation Methods and Costs

1A.7.6 Water Treatments

**Unit 1A.8 Laboratory analysis**

1A.8.1 Basic concepts

- Sampling error
- Accuracy and precision
- Repeatability (r)
- Reproducibility (R)
- Specification ranges (tolerances)
  - Simple probability calculations:
  - Normal distributions
  - Standard deviation
  - Variance
- The relevance of inter-laboratory collaborative checks

1A.8.2 Analytical Techniques

- Malt hot water extract
- Total nitrogen
- Total soluble nitrogen
- Free alpha amino nitrogen
- Moisture
- Friability
- Diastatic power
- Fermentability
- Fermentable extract
- Predicted spirit yield (PSY)

**END OF MODULE 1A**

## Module 1B: Preparation of Molasses Wort

### Unit 1B.1 Sugar Sources

#### 1B.1.1 Sources of Molasses for the Distiller

The different sources for the supply of molasses for the distiller

Sugar Cane Sugar Beet
Sugar Palm Citrus Pulp
Sweet Sorghum (Syrup)

Geographical spread of molasses production

#### 1B.1.2 Sugar Cane

1B.1.2.1 Environmental and Agronomic Factors influencing the Growth of Sugar Cane

Tropical and sub-tropical varieties of sugar cane

S*accharum. officinarum*
*Saccharum barberi*
*Saccharum spontaneum*

Principles of breeding and commercial breeding methods
Climate
Soil
Fertilisers
Irrigation
Expected plant life

1B.1.2.2 Harvesting of Sugar Cane

Factors affecting the decision when to harvest
Harvesting techniques
Factors affecting sugar yield
Disposal route for by-products e.g bagasse

1B.1.2.3 Processing of Sugar Cane to Raw Sugar and Molasses

The basic principles of the extraction process
Removal of plant materials by clarification and filtration
First, Second and Blackstrap molasses
Yield of raw sugar and molasses
Market factors influencing the composition of molasses
High test molasses
Storage of molasses

#### 1B.1.3 Sugar Beet

1B.1.3.1 Environmental and Agronomic Factors influencing the Growth of Sugar Beet

*Principles of breeding and commercial breeding methods*
Climate
Soil
Fertilisers
Irrigation

1B1.3.2 Harvesting of Sugar Beet
Factors affecting the decision when to harvest
Harvesting techniques
Factors affecting sugar yield
Disposal route for by-products e.g. animal feed pellets.

1B.1.3.3 Processing of Sugar Beet to Molasses
The basic principles of the extraction process
Yield of molasses
Factors influencing the composition of molasses
Suitability for potable alcohol production
Process energy efficiency compared to sugar cane molasses.

**1B.1.4 Sweet Sorghum**

1B.1.4.1Environmental and Agronomic Factors influencing the Growth of Sweet Sorghum
*Principles of breeding and commercial breeding methods*
Sorghum bicolor *(L) Moench*
Climate
Soil
Fertilisers
Irrigation

1B1.4.2 Harvesting of Sweet Sorghum
Factors affecting the decision when to harvest
Harvesting techniques
Factors affecting sugar yield
Disposal route for by-products e.g. ensilage as animal feed.

1B.1.4.3 Processing of Sweet Sorghum to Sorghum Syrup
The basic principles of the extraction process
Yield of jaggery/gur and syrup
Factors influencing the composition of syrup

**1B.1.5 Sugar Palm**

1B.1.5.1Environmental and Agronomic Factors influencing the Growth of Sugar Palm
Species and geographic occurance
Arenga pinnata Borassus flabellifer
Climate
Life cycle

1B1.5.2 Harvesting of Sugar Palm
Harvesting techniques e.g tapping
Factors affecting sugar yield

1B.1.5.3 Processing of Sugar Palm to Syrup/Molasses
The basic principles of the extraction process
Yield of jaggery/gur and syrup
Factors influencing the composition of syrup

**1B.1.6 Citrus Pulp**

1.B.1.6.1 Origin of Citrus Pulp
Occurrence and availability
Alternative and competing uses of citrus pulp

1B.1.6.2 Processing of Citus Pulp to Molasses
The basic principles of the extraction process
Yield
Factors influencing the composition of syrup
By-products e.g. d-limonene

**Unit 1B.2 Processing of Molasses to Wort**

1B.2.1 Composition of molasses and its relevance to the distiller
Main sugars present
Measurement by hydrometer and analysis method to measure sugars present
The importance of storage temperature on viscosity

1B.2.2 Microbiological spoilage organisms in molasses
Typical microorganisms found in molasses
Effect of these microorganisms on the processing of molasses
Effects on the final spirit of molasses infection

1B.2.3 Molasses pre-treatment
Removal of solids and scale to prevent equipment damage
Plant material Dissolved salts - gypsum
Dilution to the required °Brix for fermentation
Addition of yeast nutrients
Diammonium phosphate Ammonium sulphate
Why urea should not be used – ethyl carbamate formation
Adjustment of acidity level
Pasteurisation or sterilisation

1B.2.4 Pitching of yeast/bacteria
Light rums – Selected strain of *Saccharomyces cerevisae*
Dark Rums – Spontaneous fermentation by yeast and bacteria
Spontaneous fermentation supplemented by old stillage ("dunder")
Selected strain of *Saccharomyces cerevisae*
Selected strain of *Schizosaccharomyces pombe*
Selected strain of the bacterium *Clostridium saccharobutyricum* or another suitable bacterium

**1B.3 Laboratory Analysis**

1B.3.1 Basic Concepts

The basic concepts applied to the interpretation of analytical data

- Sampling error
- Accuracy and Precision
- Repeatability ( r )
- Reproducibility ( R )
- Specification Range (tolerances)

Simple probability calculations

- Normal distribution
- Standard deviation
- Variance

The relevance of inter-laboratory collaborative checks.

1B.3.2 Analytical techniques

The principals analytical techniques for :-

- Sugar content by hydrometer
- Sugar content by Lane Eynon method
- Total sugars as invert – TSAI
- Total sugars as Sucrose – TSAS
- Total Sweetening matter - TSM
- Acidity
- Nitrogen
- Dry Matter content

**END OF MODULE 1B**

## Module 1C: Preparation of Grape Must

**Unit1C.1 Structure and morphology of grapes**

*Vitis Vinifera* – botanical name and suitability for wine making.
Structure of the gape and grape vine
Stages of development of the plant through to harvesting.

**Unit 1C.2 Growth factors and biochemical changes in the maturation of grapes**

Influence of the following:-
- Legal requirements:-
  - Geographical areas. e.g Protected Designation of Origin (PDO) Appelation d'Origin Controllee (AOC) etc.
  - Varieties
  - Viticultural practices
  - Yields
  - Permitted treatments
- Viticultural practices
- Climate – for growing and for harvest
- Soil
- Disease and pest control

Biochemical changes occurring during grape maturation.

**Unit 1C.3 Harvesting**

Evaluation of grapes for harvesting
Determination of harvest timing
Methods used for harvesting.
Advantages and disadvantages of various methods
Factors influencing grape/must quality during harvesting.
Choice of treatments

**Unit 1C.4 Destemming/destalking and pressing**

Methods used for destemming and pressing
Advantages and disadvantages of various methods
Factors influencing grape must yield and quality.
By-products and their potential use.

**Unit 1C.5 Treatment and composition of must**

Main types of treatment that might be used and reasons for their use:-
- Solids removal
- Sulphiting
- Enzymes
- Chaptalisation/acidification
- Yeast nutrient addition (see also Unit 1C.6)

Types of must analyses
Typical values for must composition
Interpreting results
Examples of reasons for variation in must composition
Methods for changing must composition

**Unit 1C.6 Pitching of yeast/ spontaneous fermentation**

Spontaneous fermentation by yeast and bacteria
Advantages and disadvantages of spontaneous fermentation
Examples of yeasts and nature and use of wine yeast cultures
Packaging and storage conditions for yeast
Method of addition
Yeast additives/nutrients
Advantages and disadvantages of fermentation from pitched yeast

**Unit 1C.7 Laboratory Analysis**

1C.7.1 Basic Concepts

The basic concepts applied to the interpretation of analytical data

Sampling error — Accuracy and Precision
Repeatability ( r ) — Reproducibility ( R )
Specification Range (tolerances)
Simple probability calculations
Normal distribution — Standard deviation
Variance

The relevance of inter-laboratory collaborative checks.

1C.7.2 Analytical techniques

The principal analytical techniques for :-

Sugar content by hydrometer
Sugar content by Lane Eynon method
Total sugars as invert – TSAI
Total sugars as Sucrose – TSAS
Total Sweetening matter - TSM
Acidity
Nitrogen
Dry Matter content

**END OF MODULE 1C**

**END OF MODULE 1**

# MODULE 2

## Module 2: FERMENTATION, DISTILLATION & MATURATION

### Unit 2.1 Properties of Yeast

2.1.1 Yeast morphology

The principal organelles of the yeast cell and their functions:

| | |
|---|---|
| cell wall | nucleus |
| cytoplasm | plasma membrane |
| mitochondrion | vacuole |

Mechanism of reproduction by budding

2.1.2 Characteristics of culture yeasts

Principles of yeast classification

| | |
|---|---|
| concept of genus and species | cell and spore morphology |
| fermentation and aerobic growth tests | |

Identification of *Saccharomyces cerevisiae* and yeasts of natural fermentations

Tests to distinguish strains of *S. cerevisiae*

| | |
|---|---|
| growth on various carbon compounds (e.g. API tests) | |
| resistance to inhibitors | immunological reactions |

Use of small-scale (e.g. tall-tube) fermentations for evaluating yeasts

Principles of commercial yeast propagation

2.1.3 Genetic characteristics of yeast

Outline of genetic tests for typing or classifying yeasts (e.g. DNA fingerprinting)

Principles of classical hybridisation and genetic manipulation

### Unit 2.2 Yeast Metabolism

2.2.1 Carbohydrate metabolism

The principal carbohydrates in wort/must utilised by distilling yeasts

Mechanisms for transporting carbohydrate through the cell wall and membrane

Emben-Meyerhof-Parnas metabolic pathway

- conversion of hexose to pyruvate and glycerol (detailed knowledge of individual enzymes is not required)
- recycling of NAD by production of acetaldehyde, $CO_2$ and ethanol (yeast) or lactic acid (homolactic bacteria)
- generation of energy as ATP

Aerobic and anaerobic carbohydrate metabolism

- oxidative metabolism of glucose (detailed knowledge of the enzymes of the Krebs cycle is not required)
- importance of mitochondria in aerobic metabolism
- effect of concentration of fermentable sugar (Pasteur and Crabtree effects)

Significance of pyruvate as a precursor of other key metabolites

Significance of glycerol in $NAD/NADH^+$ balance

Significance of the pentose-phosphate pathway

Theoretical yield of ethanol and $CO_2$

2.2.2 Production of flavour compounds

The biochemical mechanisms for production of:
- the principal higher alcohols and esters
- the principal organic acids, including fatty acids
- diacetyl
- volatile sulphur compounds (dimethyl sulphide, $H_2S$)

2.2.3 Nutritional requirements of yeast

The sources of carbon, nitrogen, salts, metal ions and growth factors
Their importance for healthy yeast growth and fermentation
The role of molecular oxygen
- purity requirements of air

Components of wort which are not utilised by yeast

**Unit 2.3 Fermentation**

2.3.1 Yeast handling in the distillery

Advantages and disadvantages of yeast cake, yeast cream, dried yeast
Yeast storage
Preparation of yeast for pitching
Methods for measuring yeast viability and vitality
- methylene blue and similar redox dyes
- acidification power

2.3.2 Principal fermentation variables

Typical values, and the reasons for these values, of:
- wort strength
- fermentable carbohydrate
- total and α–amino N
- yeast concentration
- alcohol strength of wash
- pH
- temperature, especially at pitching

Effects of these on rate of fermentation and on production of the following flavour congeners, and the main reasons for such effects:
- acetaldehyde
- the principal higher alcohols and esters
- the principal organic acids, including fatty acids
- vicinal diketones
- dimethyl sulphide, $H_2S$ and other volatile sulphur compounds

Changes in these parameters during fermentation
The effects of different fermentation times
The basis of alcohol sensitivity and tolerance in yeast

2.3.3 Fermentation technology

Basic principles of design and operation of
- a traditional wooden washback/fermenter
- a modern stainless steel washback/fermenter

Basic principles of control of fermentation

**Unit 2.4 Hygiene**

2.4.1 Plant cleanliness and sterility

Cleanliness/sterility requirements of different stages of the process
Influence of process plant surfaces**:** cast iron, copper, stainless steel, wood
Importance of design features of pipework and fittings
Principles of layout and operation of a cleaning-in-place system
The range and main constituents of cleaning and sterilising agents
Safety requirements for handling detergents and sanitisers (e.g. COSSH)
Advantages and disadvantages of hot vs cold sterilisation
Detection and quantification of residual surface contamination:

| | |
|---|---|
| visual inspection | rinse sampling |
| swab sampling | bioluminescence sampling |

2.4.2 Types of spoilage organism

Micro-organisms which can spoil wort/must and fermentation, their origin and effects:

*Acetobacter* and *Gluconobacter*
*Escherichia* and *Enterobacter*
*Lactobacillus* and other lactic acid bacteria: good and bad effects
*Obesumbacterium* and *Zymomonas*
Wild yeasts

Factors affecting their ability to grow in wort/must or during fermentation

2.4.3 Detection methods

The principles of detection and quantification of the above micro-organisms by:

| | |
|---|---|
| microscopical examination | plate counts |
| selective media | membrane filtration |

aerobic, high-$CO_2$ or anaerobic cultivation
rapid methods: bioluminescence, conductance, polymerase chain reaction

**Unit 2.5 Pot Distillation**

2.5.1 Ethanol profiles

Ethanol profile of wash still distillation
Ethanol profile of spirit still distillation
Determination of heads/foreshots**:**spirit, spirit**:**feints/tails and end cut points
Importance of optimising ethanol recovery

2.5.2 Congener behaviour

Types of congener:

| | |
|---|---|
| more volatile than ethanol | similar volatility to ethanol |
| less volatile than ethanol | |

Recovery in wash distillation or loss in stillage
Recovery in spirit distillation:

| | |
|---|---|
| in spirit, foreshots and feints | loss in spent lees |

Effect of changes in spirit still cut points

Removal of congeners from the system
in stillage as deposits in receiver vessels

2.5.3 Pre-distillation influences on quality
Water supply
Raw materials
Culture yeast(s) and fermentation
Microbial infection

2.5.4 Still operation
Wash still operation
control of frothing cleaning of heating surfaces
control of ethyl carbamate production
Spirit still operation: distillation of foreshots, spirit and feints, cut points
Operation of standard double and triple distillation
Balanced and unbalanced operation
reasons for balanced or unbalanced operation
effects on ethanol and congener levels in LW/F receiver
Use of hydrometers in the spirit safe
Duration of wash and spirit distillations

2.5.5 Effects of copper
Thermal degradations and the role of copper, including reflux and the effect on spirit quality
Aspect ratios in still design and the effect on spirit quality
Removal of sulphur compounds by reaction with copper

**Unit 2.6 Continuous Distillation**

2.6.1 Ethanol profiles
Wash strength
Ethanol profile in the rectifier column
Control of reflux ratio
Control of distillate concentration
Legal ethanol concentrations for grain whisky spirit and neutral spirit (UK/EU)

2.6.2 Congener distribution
Types of congener:
more volatile than ethanol
higher or lower volatility than ethanol according to ethanol concentration
less volatile than ethanol
High volatile congeners in spirit and heads streams
Low volatile congeners in spent wash
Intermediate volatility congeners:
profile of congeners in rectifier column
take-off in spirit and fusel oil streams
Recycling of hot and cold feints

Recovery of fusel oil from rectifier column and recycling of ethanol
by decanter by fusel-oil still

2.6.3 Still operation
Wash strength, reflux ratio and distillate strength
maintenance of steady-state conditions
Start-up and close-down procedures
Redistillation of spirit below specification

2.6.4 Pre-distillation influences on quality
Water supply
Raw materials – cereals, molasses, grape
Culture yeast and fermentation
Microbial infection
Influence of copper in column stills (need for sacrificial copper in stainless steel stills

**Unit 2.7 Post-distillation modification of Flavour**

2.7.1 Basic concepts of maturation
Characteristics of new and mature spirit
Immature characteristics to be removed
reductive and subtractive effects
Desirable mature attributes
additive and productive reactions during maturation

2.7.2 Principal factors involved in maturation
Cask type
Spirit strength
Storage conditions, especially temperature and humidity
Effect of atmospheric oxygen

2.7.3 Properties of oak wood
Physical properties: low porosity, internal structure, resistance to cracking
Effects of arboriculture and seasoning
Chemical composition, especially cellulose, hemicellulose, lignin, tannin
Comparison of chemical and physical properties of American and European oaks

2.7.4 Cask types and properties
Manufacture of new casks
Refill casks
effect of previous use rejuvenation of casks for re-use
Matching of spirit to cask

2.7.5 General nature of maturation changes
Physical effects:
evaporation, absorption, extraction
ambient temperature and humidity

Chemical effects:
- principal wood compounds involved in maturation
- addition, subtraction and substitution changes
- alcohol strength, state of wood surface, amount of extractives

2.7.6 Non-matured spirits: gin and vodka

Quality standards of feedstock for gin and vodka production
Botanicals for distilled gin
Operation of gin still
Recovery of gin feints for re-use
Preparation and use of essences for non-distilled gin
Purification of spirit for vodka
- hydro-extractive distillation
- carbon filtration

**Unit 2.8 Quality**

2.8.1 Laboratory analytical techniques

Alcohol content
Volatile congeners by GLC
Non-volatile congeners by HPLC (or TLC if appropriate)
Phenols and tannins
Nitrosodimethylamine
Ethyl carbamate and its precursor
Dimethyl sulphide and polysulphides
Colour of matured spirits

2.8.2 Sensory Analyses

The basic facilities necessary to conduct nosing tests
The procedure, typical applications and methods of reporting:
- difference tests (triangle, paired comparisons, duo-trio, A or not-A, two out of five)
- descriptive tests (flavour profile, ranking, threshold)

The interpretation of "statistical significance" results
The role of flavour standards and training in sensory assessment
Sensory analyses for new spirit and matured and non-matured spirit beverages

2.8.3 Quality Management

The difference between Quality Control and Quality Assurance
Basic principles of Quality Assurance concepts, including:
- international standards, e.g. ISO 9000 series
- total quality management
- critical control points and HACCP

Basic principles and purpose of laboratory standards, e.g. NAMAS

## END OF MODULE 2

# MODULE 3

## MODULE 3 PROCESS TECHNOLOGY

### Unit 3.1 Distillation

3.1.1 Distillation theory

Principles of distillation in a single-column still
Vapour/liquid equilibrium in ethanol/water distillation
Relationship between relative volatility and ethanol concentration
Theoretical plates
Multi-plate VLE diagram
- operating lines — reflux ratio
- determination of theoretical number of plates (McCabe-Thiele)

Deviations from theoretical behaviour
- incomplete equilibration — condensation and reflux

Azeotropes

3.1.2 Design and operation of continuous stills

Basic single-column continuous still
- separate stripping and rectifying sections
- reflux return from top condenser
- requirement for wash pre-heating
- comparison of steam injection and reboiler for heating

Two-column still system for grain whisky spirit and grain neutral spirit
- advantages of separate stripping and rectifying columns
- requirement for wash pre-heating
- control of flow rate and temperature of wash feed
- transfer of vapour and hot and cold feints between columns
- spirit strength: legal requirements

Multi-column still system for neutral spirit
- hydro-extractive distillation — recovery of alcohol/water azeotrope
- removal of feints and volatile heads

Material balance over the distillation process
Plate design
- principal requirements: passage of vapour, but liquid retention
- number and size of holes: principles for analyser and rectifier plates
- downcomers, weirs (seal pots), bubble caps and safety valves

3.1.3 Design and operation of pot stills

Relationship of still size to mash tun and washback capacity
Material balance over the distillation process
Relative size of wash and spirit stills
Design and construction of stills:
- importance of copper
- still body: shape, filling level, heating arrangements

still neck: effect of neck design on reflux
vapour pipe slope and implications for reflux
additional reflux by neck plates, neck condenser or "purifier" in the vapour pipe
relief valves for pressure and vacuum

**Unit 3.2 Heat Transfer**

3.2.1 Principles of heat transfer

The meaning of specific heat
Knowledge of the formula for heat transfer rates across heating/cooling surfaces of newtonian fluids under turbulent flow conditions
Calculations of heat requirements for mashing and distillation
Heat exchange calculations between liquids in distillery applications
Conduction of heat:
heat transfer calculations across a surface of a vessel
Convection of heat:
simple heat transfer calculations between two fluids
factors affecting efficiency of heat transfer in boiling and condensation
Radiation of heat
examples of its importance in distilling
the definition of emissivity
Simple calculations of heat loss by convection and radiation

3.2.2 Heating of process liquids

Typical heat transfer systems used in mashing
Heat transfer and steam supply in cereal cooking
Heating of pot stills by
direct firing (coal, gas or oil)
simple steam coil
steam coil with heating pans
Heating of column stills
steam injection
calandria (reboiler)

3.2.3 Condensation of distillate

Advantages and disadvantages of worm, shell-and-tube and multi-plate condensers
Condenser layout and operation
single- or multi-pass tube condensers
temperature of inlet and outlet water
after-cooling of distillate
Simple calculations on condensation and cooling of distillate
Efficiency of heat recovery
Uses of recovered heat

3.2.4 Cooling of wort and spent wash

The basic principles of design and operation of heat exchangers for cooling wort, spent wash, pot ale and spent lees
Typical values in these applications for temperature of liquids in and out, and cooling water: hot liquid ratio
Simple heat balance calculations

**Unit 3.3 Energy**

3.3.1 Combustion

The definition of calorific value of fuels
Factors that affect the selection of fuels for malting and distilling: coal, peat, liquid and gaseous hydrocarbon fuels
The derivation of simple mass balances in combustion
Fuel**:**air ratio
Typical composition of flue gas
energy recovery from flue gas

3.3.2 Steam raising

The meaning of

| | |
|---|---|
| sensible heat | latent heat of vaporisation |
| enthalpy | dry (superheated) steam |
| wet steam | |

Basic principles of design and operation of a fire-tube boiler
Principal steam requirements for distillery plant

| | |
|---|---|
| cereal cookers and accumulator | pot stills |
| continuous stills | stillage processing |

Temperature - enthalpy (T-Q) diagram in distillery operation
Simple calculations of enthalpy of steam
Steam regeneration

| | |
|---|---|
| thermocompressor | reboiler |
| mechanical vapour recompression | |

**Unit 3.4 Effluents and Co-products**

3.4.1 Effluent composition

The meaning, and relevance to distillery effluent, of:

| | |
|---|---|
| biological oxygen demand | chemical oxygen demand |
| suspended solids | pH |

Relative contributions of different departments to composition of effluent:
Typical of:
water use in spirit production
effluent volume from spirit production
BOD and COD (dichromate) of main effluent streams
suspended solids of main effluent streams
pH and temperature range

Effluent analyses
BOD, COD total suspended solids
Awareness of official requirements for effluent discharges
Precautions and requirements for disposal of used detergents/sanitisers

3.4.2 Effluent treatment
Calculation of effluent treatment costs (Mogden formula)
The basic principles of treatment of effluent discharges
pH control prior to treatment
aerobic digestion (biofilters)
anaerobic digestion
spraying on farmland
discharge to sea
Environmental implications of these methods
Removal of copper from effluent (precipitation, electrolysis)

3.4.3 Processing of distillery stillage (pot ale, spent wash )
Processing of co-products (draff, pomace)
Separation of solids and liquid of spent wash
decanter centrifuge
screw press
Factors affecting their capacity to clarify to desired solids concentration
Evaporation: basic principles of
natural- and forced-circulation evaporators
falling film evaporator
multiple effect evaporation
Drying of animal feed
disc dryer drum dryer
spray dryer cyclone dryer
Energy efficiency in processing
Separation of useful sub-products – e.g. red colour from pomace
Preparation as fodder or fertilizer
Preparation as substrate for further distilled products e.g. marc, orujo, grappa etc.

3.4.4 Carbon dioxide
Collection of $CO_2$ from fermentation vessels
Processing of $CO_2$
purity requirements
layout of purification plant
knowledge of the function of each column

**Unit 3.5 Fluid Flow**
3.5.1 Basic characteristics
Definition of newtonian and non-newtonian fluids
their relevance in the distilling industry

Definition of laminar and turbulent flow
their relevance in the distilling industry
the relevance of Reynolds number velocity profiles in pipes
The meaning of conservation of mass in liquid flow
simple calculations on volume flow, velocity and pipe diameter
Conservation of energy in fluid transfer
Bernouilli equation simple energy balance calculations
examples of energy interchange in fluid transfer

3.5.2 Valves
The basic design features, respective merits and typical distillery applications of the following types of valve:
butterfly diaphragm
gate globe
Design features and applications in distillery plant of the following types of valve:
pressure relief pressure reducing
anti-vacuum

3.5.3 Design of pipework
The concept of pressure drop and Fanning friction factor in pipework systems
effect of change of diameter
relative effects of bends, valves, T-pieces etc.
effect of internal surface roughness
The characteristics of product flow most favourable to product quality, and the important pipe-run features for water, wash, hot feints, spirit and whisky

3.5.4 Pumps
The factors affecting the power requirement of a pump
The importance of NPSH (net positive suction head)
Calculation of power requirements in typical applications
Basic design features, priming and pumping characteristics, respective merits and typical distillery applications of the following pumps:
single stage closed impeller centrifugal
single stage open impeller centrifugal
diaphragm positive displacement
lobe rotor

**Unit 3.6 Materials of Construction**

3.6.1 Properties of materials
The reasons why copper and stainless steel are the preferred materials for certain items of distillery plant
The advantages and disadvantages of the following for distillery applications:
wood copper
cast iron mild steel
lined mild steel stainless steel

3.6.2 Stainless steel

The principal properties of austenitic stainless steels

The important features of grades AISI 304, 304L, 316 and 316L

- ingredients
- relative corrosion resistance
- mechanical strength
- expansion coefficients
- heat transfer coefficient
- relative cost

Applications where austenitics are unsuitable and duplex or ferritic steels are required.

3.6.3 Corrosion

The common forms of corrosion in copper, and their causes

The common forms of corrosion in stainless steel, and their causes

3.6.4 Insulation

Principles of effective insulation

Typical materials and reasons for their selection for:

- process streams above ambient temperature
- process streams below ambient temperature

**Unit 3.7 Instrumentation and Process Control**

3.7.1 Essentials of practicable remote measurement

Typical conditions that affect selection and siting of remote sensors:

- environmental and safety
- product composition and temperature
- cleaning and sterilisation procedures
- sensor accuracy and repeatability
- sensor reliability and maintenance requirements

3.7.2 Remote measurement systems

The basic principles of design and operation of common forms of remote sensor for measuring:

- temperature
- density/specific gravity
- flow rate of process fluid
- liquid level
- ethanol
- pH

Recent developments

3.7.3 Basic principles of process control

The meaning of sequence (discontinuous) control

- typical applicatons
- the function of a programmable logic controller (PLC)

The meaning of process (continuous) control.

The nature and purpose of

- an electronic controller
- a transducer
- a control element

The principles of a closed loop control system

Definitions, characteristics and applications of the following types of control:

- on – off
- differential gap
- time proportioned
- proportional, integral and derivative (PID)

The basic characteristics required of a flow control valve in these situations

3.7.4 Computer control

The basic requirements of a computer and PLC control system

The basic principles, respective merits and distillery applications for commonly used computer control systems

- a micro computer control system
- a mini computer control system
- a distributed control system

**Unit 3.8 Packaging Processes**

3.8.1 Organisation of blending

The purpose of blending, and the need to meet any legislative requirements for product type.

Consistency of blend

Significance of stated age of blend

Management of stocks for correct age at blending

3.8.2 Prevention of haze

Distinction between haze and floc

Relevance of the heads/foreshots cut

Removal of haze by precipitation of fatty acid esters and chill-filtration

Prevention of floc by use of de-mineralised water and chill-filtration

3.8.3 Refrigeration

Reasons for chilling spirit prior to filtration; advantages and disadvantages

Basic principles of the closed circuit vapour-compression refrigeration cycle

3.8.4 Filtration

The principles of design and operation, relative merits and typical performance of**:**

- a plate and frame filter
- a leaf filter
- a candle filter

Range of suitable filter media

Filter performance as a function of

- time, temperature, pressure
- filter medium
- dosing rate of filter aid
- particle size and concentration in spirit

3.8.5 Packaging

Primary packaging materials

- basic properties of glass and PET
- principles of manufacture
- typical faults
- marketing impact
- environmental implications

The basic principles of design and operation of equipment for

| | |
|---|---|
| bottle rinsing | bottle filling |
| fill level control | labelling |

Secondary packaging materials
- basic properties
- influence on operation of packaging line and product image

3.8.6 Packaging Line Design

A basic understanding of packaging line design theory

| | |
|---|---|
| "V" graph | queuing theory and line balance |
| accumulation | use of variable speed equipment |
| handling of materials | handling of rejects and waste |

A basic understanding of systems to measure packaging line performance
- plant efficiency
- planned down-time including cleaning, maintenance and change-over of bottle size or product
- unplanned down-time including non-availability of product, materials or services
- mechanical down-time.

**Unit 3.9 Health & Safety**

3.9.1 Fire and explosion risks of ethanol

Flash points of aqueous alcohol solutions
Flammable and explosive concentrations of alcohol vapour
Fire and explosion risks of alcohol, and their prevention,

| | |
|---|---|
| in batch and continuous distillation | in storage and maturation |
| in blending and packaging | in leakage or spillage |

3.9.2 Carbon dioxide

Physiological effects of $CO_2$
Dangers of working in fermentation vessels and surrounding areas
Safety precautions

## END OF MODULE 3

## END OF SYLLABUS