# THE SCIENCE BEHIND DOUGH QUALITY

EXPLORING HOW A RAINY DAY CAN RUIN YOUR DOUGH!

A TEACHING UNIT FOR YEAR 10 AND 11 SCIENCE STUDENTS







## About the GRDC

## The GRDC

The Grains Research and Development Corporation is a statutory authority established to plan and invest in research, development and extension (RD&E) for the Australian grains industry.

Its primary objective is to drive the discovery, development and delivery of world-class innovation to enhance the productivity, profitability and sustainability of Australian grain growers and benefit the industry and the wider community.

Its primary business activity is the allocation and management of investment in grains RD&E.

## **GRDC** Vision

A profitable and sustainable Australian grains industry, valued by the wider community.

## **GRDC** Mission

Create value by driving the discovery, development and delivery of world-class innovation in the Australian grains industry.

## **GRDC Values**

- We are committed and passionate about the Australian grains industry.
- We value creativity and innovation.
- We build strong relationships and partnerships based on mutual trust and respect.
- We act ethically and with integrity.
- We are transparent and accountable to our stakeholders.

## Contact

TELEPHONE:	02 6166 4500
FACSIMILE:	02 6166 4599
EMAIL:	grdc@grdc.com.au
NTERNET:	www.grdc.com.au

Title: The science behind dough quality – Exploring how a rainy day can ruin your dough! Project Code: AGC00001 Authors: AgCommunicators JUNE 2016

©Grains Research and Development Corporation 2016

#### All Rights Reserved

This publication is copyright. Except as permitted under the Australian Copyright Act 1968 (Commonwealth) and subsequent amendments, no part of this publication may be reproduced, stored or transmitted in any form or by any means, electronic or otherwise, without the specific permission of the copyright owner.

#### Disclaimer

Any recommendations, suggestions or opinions contained in this publication do not necessarily represent the policy or views of the Grains Research and Development Corporation. No person should act on the basis of the contents of this publication without first obtaining specific, independent, professional advice. The Corporation and contributors to this publication may identify products by proprietary or trade names to help readers identify particular types of products. We do not endorse or recommend the products of any manufacturer referred to. Other products may perform as well as or better than those specifically referred to. The GRDC will not be liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information in this publication.

# Contents

GRD	C Vision	2
GRD	C Mission	2
GRD	C Values	2
Cont	act	2
1.0	Teaching the science of grains	4
2.0	Learning outcomes and curriculum links	5
3.0	Teaching Unit Content and Overview	6
4.0	Insight Food chemistry from seed to stomach	8
5.0	Activity Food factors	9
6.0	Activity Water and growing food	10
7.0	Insight Can a rainy day ruin your dough?	12
	Brainstorm What environmental factors do grain and pulse farmers face in Australia?	12
	Growing Grain for Human Consumption	12
8.0	Insight Wheat morphology	13
9.0	Practical Investigating the reaction rate of yeast	16
10.0	Insight Wheat quality	18
11.0	Insight Understanding proteins	. 20
12.0	Practical The Biuret Test	21
13.0	Insight The effect of rain on dough	. 22
14.0	Practical Making dough from rain damaged grain	. 23
	Practical Questions Making dough from rain damaged grain	. 25
15.0	Insight Food chemistry	. 26
16.0	Activity Sugars and Enzymes	. 27
17.0	Insight Enzymes and sugars	. 28
18.0	Insight Catalysts and starch	. 29
19.0	Practical Testing for starch and the effect of alpha amylase	. 30
20.0	Good Reads	. 34
21.0	References	. 34

# **1.0 Teaching** the science of grains



The Grains Research and Development Corporation has invested in the development of a suite of user-friendly grain education resources and initiatives for students, teachers and families.

These resources have been developed with teacher and researcher input and have been designed following a comprehensive survey of more than 340 teachers throughout Australia.

In each of our curriculum-linked resources we have worked to incorporate a range of lesson plans which explore the latest science, technology, engineering, mathematics, nutrition, research and innovation in the Australian agricultural industry. You can use these resources as a unit or select components to complement your teaching plan.

Using an investigation and inquiry based approach students will touch, try, taste and even smell the science of the Australian grains industry. It provides an ideal and relevant teaching context to engage students in food production.

Specifically, resources are available to address the food and fibre curriculum descriptors in geography, science, home economics and agriculture.

We hope you have fun teaching with these resources. Please contact us for more information.

Kind regards
The GRDC Education Team

# **2.0 Learning outcomes and curriculum links**

## About the Science Behind Dough Quality

Australia is very lucky to have high quality produce including grains and pulses. This is a reflection of the industry's depth of scientific research and development, application of best practice methods and constant review and innovation of processes. The quality of wheat grain is of particular interest, being the largest crop in terms of amount grown and contribution to the economy.

Wheat is produced using best paddock practices, scientific understanding and application and good weather. Throughout the entire season, farmers must monitor their crop to ensure they are doing everything they can to achieve a high yield at harvest time and a good quality grain for consumers. At every step of the way, chemical reactions govern the growth and development of this grain. It must have enough protein, adequate starch content and optimal moisture level for a high end quality product.

## **Overview**

With a chemistry and earth science focus, students are to explore the influence of chemical and physical changes in grain, from seed to stomach, for success in growing and processing. The resource provides insight and activities which ask students to think about the environmental effects on molecular change. Key words and scientific concepts are introduced with reference to real-world challenges while simple practicals based on quality assurance provide insight into the application of scientific concepts.

## Learning outcomes

Students should be able to

- Confidently convey an understanding of the water cycle in relation to producing food.
- Explain the effect of chemical reactions and how different factors influence their rate.
- Explore practical applications of theories and how they are used in industry.
- Employ science inquiry skills to conduct, evaluate and communicate investigations into the properties of mixtures and changes in chemical reactions.

## Australian Curriculum Content Descriptions

## Science Understanding Chemical Science

Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187)

## Earth and Space Science

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere(ACSSU189)

## Science Inquiry Skills Planning and Conducting

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)

### Processing and analysing data and information

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence(ACSIS204)

### Communicating

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)

## **Chemical Sciences**

Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187)

# **3.0 Teaching unit content and overview**

This resource contains a range of curriculum-linked lesson plans which teachers can cut, paste, and utilise as they see fit. Our team work to develop resources which are interactive, fun and fit into your busy teaching schedule. The below table summarises the wide modes of engagement strategies – activity supported insights, exploring critical and lateral thinking and inquiry. You can use some of these lesson plans or all. Whatever you do, we hope you have fun teaching your students about emerging technologies enhancing approaches to growing great grain.

PAGE 8	<b>4.0 Introduction</b> Food chemistry from seed to stomach	Food chemistry starts from the time a seed is planted in the paddock until we are digesting its end product. Ask students to think about all the naturally occurring and catalysed reactions which happen through the journey from seed to stomach. These may be chemical reactions or physical changes of state.	
PAGE 9	5.0 Activity Food factors	Engage students in thinking about the effect of each sphere on growing food. Each sphere provides benefits and presents challenges. Students are to label pictures which represent the lithosphere, hydrosphere, biosphere and atmosphere before brainstorming factors which would be of interest in each sphere in growing food and fibre.	
page 10	<b>6.0 Activity</b> Water and growing food	Exploring the water cycle and its interactions between each sphere, students show their understanding through labelling a diagram. Students should recognise why each physical change and movement of water is important to understand as a cereal farmer.	
page 12	<b>7.0 Insight</b> Can a rainy day ruin your dough?	In order to produce high quality, high yielding wheat, grain growers must employ scientific research and development, good monitoring and management practices and historical and real-time data.	
		Engage students by presenting them with the following challenge which emulates research and practical applications of the grains industry.	
		<b>Issue:</b> Good quality grain is paramount for good quality food. Grain is assessed for quality assurance and this step can expose damage from weather. For example, evidence of germination in harvested wheat indicates an untimely rain event has occurred. This germination degrades starch and gluten and affects bread and pasta quality.	
		Solution: It is possible to test the grain for starch and protein quality.	
		Your task: Investigate the effects of weather damage on dough quality and behaviour.	
		Discuss with students the need for farmers to stay informed and updated about how their crops grow, how they are affected by external factors and how what happens in the paddock will affect the resulting quality of grain and their products.	
PAGE 13	<b>8.0 Insight</b> Wheat morphology	To set students up in understanding this issue, work through this insight into the morphology of wheat and how its structure and chemistry changes in the journey to becoming a loaf of bread.	
PAGE 16	<b>9.0 Practical</b> Investigating the reaction rate of yeast	This simple experiment will illustrate to students the effect of temperature on yeast activity. Students will produce a science investigation report with a hypothesis and discussion which displays understanding and appropriate variable and organisation of data. This practical could also be completed using a pressure sensor and logger set up. It could be extended by additionally investigating the effect of the amount of substrate (in the form of glucose) on yeast activity. *The term 'sugar' is often used as a generic term for monosaccharides or more specifically,	
		sucrose. Ensure this is understood by students.	

PAGE 18	<b>10.0 Insight</b> Wheat quality	Begin by asking students what products they know that are made of wheat. Do they know why these products have different structure and function if they are all made out of the same crop? It's all about protein quality – not every wheat harvest is the same! This insight provides an explanation of the difference between protein quality and content and how determining each of these factors governs what food the grain may be used to create.
page 20	<b>11.0 Insight</b> Understanding proteins	This insight provides students with background information on protein, focusing on the gluten protein.
PAGE 21	<b>12.0 Practical</b> The Biuret Test	Poor quality protein can be a result of weather damaged grain. The Biuret Test looks at the presence of peptide bonds. Practical notes Ideally teachers will need to obtain some weather damaged grain or poor quality flour. In its absence, use any high quality grain which can be obtained and discuss what results would be expected in weather damaged grain. Teachers are to remind students that as these experiments are conducted in a laboratory, no samples should be eaten – particularly weather damaged wheat and flour samples which can potentially have mould.
	Brainstorm	Grain growers must ensure they are updated on the weather. Ask the students to think about the challenges and benefits of growing grains and pulses in the Australian environment. Ask students to find a map showing the Australian grain belt – why do we choose to grow grains and pulses in these environments?
PAGE 22	<b>13.0 Insight</b> The effect of rain on dough	Explore the effect of external factors on grain quality. Start by asking students to think about all the reactions which happen along the journey from seed to stomach. Introduce enzymatic hydrolysis by focusing on the effect of rain on wheat crops which are ready to be harvested.
	Read	This short article from the ABC is an example of how weather affects wheat production. 'Wheat price rally on back of US wet weather', <b>http://www.abc.net.au/news/2015-06-29/</b> <b>wheat-prices-rally-on-back-of-us-wet-weather/6580572</b>
PAGE 23	<b>14.0 Practical</b> Making dough from weather damaged grain	Teachers can select this simple practical as an introduction to wheat flour quality. This practical is reflective of the attributes that particularly interest millers, bakers and consumers.
PAGE 26	<b>15.0 Insight</b> Food chemistry	Exploring the link between rain, enzymes and starch, this insight sets students up for the activities and practicals which follow.
	Watch	To introduce hydrolysis by enzymes, watch this video by the Khan Academy: https://www.khanacademy.org/science/biology/macromolecules/carbohydrates-and- sugars/v/hydrolysis
PAGE 27	<b>16.0 Activity</b> Sugars and enzymes	With a focus on starch, this activity asks students to look at its molecular structure, including formula and carbohydrate classification. Sections of this task can be selected to scale learning. Ensure that students can explain the role of starch in grain before exploring how enzymes break down carbohydrate molecules.
		To engage students, ask them to place a piece of white bread on their tongue without chewing. What can they taste? What is happening to the starch molecules in the bread to change the taste?
PAGE 29	<b>18.0 Insight</b> Catalysts and starch	Providing an overview of the interaction of enzymes and substrates in reactions, this insight sets students up for understanding of the following practicals.
page 30	<b>19.0 Practical</b> Testing starch	Using iodine, this practical focuses on the presence of alpha amylase. If starch is detected then germination has not been catalysed by the presence of the enzyme, and vice versa. In part two, students can explore the effect of temperature on amylase in the conversion of starch to maltose. For assessment, students are to complete a science investigation report.

## 4.0 INSIGHT Food chemistry from seed to stomach

We know that when we gobble that bowl of cereal, eat that yummy sandwich or slurp that big bowl of pasta, our body will start to break down that food through a serious of mechanical and chemical reactions. The crunching action of our teeth and churning movement of our stomach will mechanically break down the food into smaller pieces.

Enzymes then act upon these pieces, causing chemical reactions involving the three main nutrients: carbohydrates, proteins and fats. This process helps our body to absorb the products of our food into the blood stream so they can go where they are needed. But there is much more to food chemistry than what happens in our body.

When we eat a meal, we may not think about all the reactions and changes that happen before that first bite. Chemical and physical changes start out in the paddock. Plants all have their own chemical processes by which they grow and move energy through the system. Plants, like grain crops, have processes which are governed by the environment around them from the time seeds are planted in the ground until they are harvested.

Products which are harvested can be further altered physically and chemically. They can be ground in mills or

have temperatures applied to cause physical changes. Catalysed chemical reactions can be applied in food processing methods and grains can be refined to extract their molecular parts with these used to create new foods or ingredients. So many physical changes and chemical reactions before we can even think about eating!

Scientists and grain growers need to understand all of the physical changes and chemical reactions, naturally occurring and applied, which govern the transfer of energy from the environment to the plant and the plant to us.

## Brainstorm

With a partner, list one chemical reaction and one physical change for each stage.



GROWING AND HARVESTING	PROCESSING & MANUFACTURING	CONSUMING

# **5.0 ACTIVITY** Food factors

In order to survive, living things have been foraging for food in the *biosphere* for thousands of years. Some find their food deep in the ground, in the dark depths of the ocean or high up in the atmosphere, while others find food on the surface of the earth. Every living thing has been equipped with a unique physical ability to ensure it can feed itself through external or internal means.

Food in the biosphere is reliant on the processes of the surrounding spheres: the lithosphere, the atmosphere and the hydrosphere. The *lithosphere* includes the core of the earth, the surrounding crust and rock, the soil and even the sediment in the water and the dust in the air. The *hydrosphere* includes all forms and bodies of water from ground water, lakes and dams, oceans, icebergs and even the small molecules of water in the air. The *atmosphere* is where weather occurs and contains all the gases that living things need in balance to survive, including nitrogen, carbon dioxide and oxygen.

## Look at the pictures below and label which best represents each sphere:









Humans rely on understanding as much as they can about each of these spheres in order to grow food and fibre.

## Use your understanding of each sphere to list factors which would be of particular interest to a farmer or agricultural scientist about each sphere.

ATMOSPHERE	
BIOSPHERE	
HYDROSPHERE	
LITHOSPHERE	

# 6.0 ACTIVITY Water and growing food

In growing food and fibre here in Australia one factor which is discussed, monitored and managed on a daily basis is water. Australia relies on water being available from rivers, lakes, reservoirs, dams, water tanks, bores and is totally reliant on rain and snowfall (precipitation) to fill these. Every region of the country stores this water differently because the annual precipitation varies so much from place to place. Some areas receive average annual rainfalls of up to 1,500 millimetres, while many receive less than 300 millimetres annually!

Growing enough food for everyone takes a lot of water. In 2009, the Australian Bureau of Statistics reported that 52 per cent of the nation's total water consumption was allocated to agriculture. Only one per cent of this was used to water crops through irrigation, with most cereal farmers relying on rain. This is why farmers are so interested in the cycling of water. They want to know how much water is being lost and gained through the atmosphere, how much water the plants need, how water moves and is stored in the soil and what the best way is to store water.

## ACTIVITY

## Read the following description and link it to the correct term.

Water being taken up into the plant from the soil via the roots CONDENSATION A cloud is formed when water vapour in the air is converted **EVAPORATION** to a liquid in the form of small droplets Water is carried through the root and stem of the plant, ABSORPTION whereupon reaching the surface of the leaves, converts to a vapour and is released into the atmosphere SURFACE RUN OFF Water is lost to the atmosphere from a body of water when it converts from a liquid to a gas INFILTRATION Water on the ground flows over its surface TRANSPIRATION The fall of water from the atmosphere to the ground surface, such as rain

Water on the ground surface enters the soil

Movement of water below the surface of the ground

GROUND WATER FLOW

## Water and growing food

This diagram shows the cycling of water through the biosphere, lithosphere, hydrosphere and atmosphere.

## ACTIVITY

## Label the diagram using the following 'spheres' and 'movement of water' terms.

## Spheres

Atmosphere, Biosphere, Lithosphere, Hydrosphere

## Movement of Water

Condensation, Evaporation, Absorption, Surface Run-Off, Infiltration, Transpiration, Ground Water flow, Precipitation

## **Brainstorm**

You are a farmer growing cereal grain crops. Discuss with your peers what technologies you could use to monitor the water cycle in relation to your crop.



# 7.0 INSIGHT Can a rainy day ruin your dough?

Producing wheat for human consumption takes the right mix of science, good weather (or luck!), great management and sustainable farming practices. A farmer must manage the grain throughout the season to ensure its overall quality. They must get everything right from the variety selection, the nutrients applied through to the way the grain is harvested and stored. They also need the right amount of rain to fall at the right time of the season, as too much or too little can be detrimental to the plant's growth and development. In particular, growers do not want it to rain after the grain is ripe because this changes the quality of the grain and that of the products made from it.

## Growing grain for human consumption

There are many different types of wheat grown throughout Australia. There are bread wheats, yellow alkaline noodle wheats, pasta wheats, and wheat for flat breads and pocket breads, wheat for white udon noodles and wheats for baking bakery products. Each has their own specific quality traits which influence how they behave when kneaded, baked, cooked, boiled or fried.

## Can you think of different wheat products and how they taste and behave? Which is your favourite?

Farmers have a large responsibility to deliver wheat of a certain quality. Their quality is judged at the silo where the grain delivered undergoes a series of rigorous testing, investigating attributes such as grain hardness, grain colour, protein content and the different dough strengths needed for various end products. Dough strength is largely determined by protein content and quality (Blakeney et al 2009).

Protein content, structure and quality is perhaps one of the most important traits as it is critical for end-product quality. All of these can be affected by physical and chemical changes which occur throughout the journey of grain. Australia produces about 24 million tonnes of wheat 24 million tonnes of wheat per year, which is 3.5 per cent of the world's annual production. Western Australia and New South Wales are the largest production states (AEGIC 2016).

## Brainstorm

What environmental factors do grain and pulse farmers face in Australia?



# 8.0 INSIGHT Wheat morphology

The average wheat kernel (Kent, 1983 cited in Blakeney et al 2009) is comprised of more than 80 per cent endosperm, eight per cent bran and seed coat material, six per cent aleurone (outer layer of the endosperm) and between three and four per cent embryonic tissue (scutellum and embryonic axis).

- The bran is the outer layer which contains antioxidants, B vitamins and fibre.
- The germ is the embryo, which means it has the potential to germinate and form a new plant. It contains B vitamins, protein, minerals and healthy fats.
- The endosperm is the largest tissue of the grain and is predominantly made up of starch (Blakeney et al 2009). It contains 8 to 16 per cent protein and a small amount of vitamins and minerals. The endosperm serves as the food supply for the germinating seedling.

## Figure 1: The wheat grain showing the bran, germ and endosperm.



(Reproduced with permission: Wheat Food Council, Canada)

## The chemistry of turning flour into bread

A common product we make out of wheat is flour, which is then used to produce bread. To make flour, the grain is milled (or ground) between stone or steel wheels. Millers can choose to make a whole-grain flour, which uses the whole grain (the bran, the germ and the endosperm) or make a white flour, which uses the endosperm only (the bran and germ are sieved leaving the endosperm).

While often taken for granted, the simple process of bread making causes a unique set of reactions occur. It's kitchen science in action – here's how:

MIXING: Firstly, the dry ingredients flour, sugar and yeast are mixed. Water is then added and kneading begins. The physical action of mixing and kneading causes a reaction between the endosperm proteins, this causes the proteins to swell, become flexible and stretchy – forming a protein complex known as 'gluten'. Under an electron scanning micrograph it is possible to view the formation of this gluten matrix.

Figure 2: Gluten complex in a well-kneaded dough. Note the net-like matrix which can trap the gas bubbles produced by the yeast.



Image sourced from Associate Professor Daryl Mares (University of Adelaide).

The gluten matrix consists of glutenin proteins bonding to each other through disulphide bonds, forming long chain like polymers. Kneading of the dough causes disulfide bridges to be repeatedly severed and then re-established until a threedimensional glutenin network forms, consisting of glutenin polymers with globular gliadins embedded between (www. chemistryviews.org).

Figure 3: Gluten protein's structure, where gliadins are represented by spheres and glutenins by filaments.







As you continue to knead the bread, the gluten network

continues to strengthen with these glutenin sheets. The

image below shows how the dough expands (the gluten

molecules uncoil and reveal far more inter-molecular

hydrogen bonding opportunities), and then contract.



(Rueben, Coulta et al, 2016)

(Miguell et al 2009)

2 FERMENTATION: This is when the dough comes alive! As the dough sits in a warm place, the live yeast microorganisms feed on sugars and carbohydrates (starch) present in the dough. Enzymes present in yeast and flour work to catalyse or increase the rate of this reaction. The energy is used by the yeast for growth and further activity. In the presence of oxygen, the following reaction occurs.



As the yeast releases carbon dioxide, the gluten matrix then traps  $CO_2$  released by the feeding yeast microorganisms. This is easily observed through the dough rising.

**3** PROOFING: After the dough has risen, it is again kneaded to release any large bubbles that may have formed and encourage more uniform bubble formation. A second proof occurs, allowing the gluten matrix to again trap carbon dioxide and rise.

**BAKING:** Our favourite phase... This takes the average tasting dough and turns it into bread... Baking or heat triggers the following:

- a. The carbon dioxide gas inside the dough expands, causing the dough to rise.
- b. The carbon dioxide in solution in the dough turns into gas (at 40  $^{\circ}\text{C}$ ).
- c. The rate of activity of the yeast cells and fermentation increases until the dough reaches the temperature at which yeast dies (approximately 46°C). Once the yeast dies, it does not use the extra sugars produced between 46-75°C. These are available to sweeten the breadcrumb and produce the brown crust colour.
- d. From about 60°C onwards, stabilisation of the crumb begins.
- e. Starch granules swell at about 60°C, and in the presence of water released from the gluten, the starch granules burst and the starch released forms a thick gel-like paste that helps form the structure of the dough.
- f. From 74°C onwards, the gluten strands surrounding the individual gas cells are transformed into the semi-rigid structure commonly associated with bread crumb strength.
- g. The natural enzymes present in the dough die at different temperatures during baking. One important enzyme, alpha-amylase, the enzyme which breaks starch into sugars, keeps on performing its job until the dough reaches about 75°C.

The gluten network trapping the carbon dioxide bubbles and the end product – bread and an electron micrograph image of the endosperm starch which helps to set bread. Note this is a crystalline granule embedded in a protein matrix



(D.Mares, 2015)

# 9.0 PRACTICAL Investigating the reaction rate of yeast

We know there are changes occurring throughout the entire journey of wheat. From a seed in the paddock to the food in the pantry, these changes are in part the result of chemical reactions and these reactions can be influenced by external factors. The catalysing enzymes which break down the molecules inside wheat can be slowed or accelerated by the external factors of temperature and amount of substrate available for the enzyme to act upon. An example of this can be found in baking bread.

When bread dough is made, the organism yeast is included in the mix of flour, water, sugar and any other ingredient the baker chooses to add. Yeast is an organism whose internal temperature is determined by the surrounding environment, including the external temperature. Yeast breaks down the molecules within the mix, turning glucose from starch into carbon dioxide and alcohol in the form of ethanol. This process is called fermentation. Inside the dough, the yeast is working in anaerobic conditions, meaning it has no oxygen.



The carbon dioxide produced is trapped by the gluten matrix of the dough and creates bubbles. As the bubbles cannot escape, the bread dough rises. However, if the yeast is not warm it will not work and the bread will not rise because the yeast will burn the glucose too slowly to release sufficient carbon dioxide bubbles.

## Your task is to investigate the effect of temperature and substrate on the behaviour of yeast.

## **Materials**

- Water
- Dried yeast
- 5% glucose solution
- Water bath
- Thermometer
- Pipette
- Timer
- Test tubes
- Rubber bung for test tube with delivery tube attached
- 2 X 400ml beaker

## Method

- 1 To a 400ml beaker, add 200ml of water. Using the water bath, heat the water to 60°C
- 2 Add 5g dried yeast to a test tube and using the pipette, add 10ml of glucose solution. \*Do not mix or shake.
- 3 Seal the test tube with the rubber bung and delivery tube.
- 4 Place the test tube apparatus into the beaker.
- 5 Place the other end of the delivery tube into a second beaker which contains 200ml of room temperature water.
- 6 Over five minutes, observe and record how many carbon dioxide bubbles appear in the second beaker.
- Repeat for each temperature displayed in the table below. Ensure that the water in the beaker is the correct temperature before placing the test tube in it. Ensure that the yeast + glucose mix is replaced each time.

TEMPERATURE °C	
10	
20	
30	
40	
Room temperature	



### **Understanding Australian wheat quality**

Protein in wheat (%)



Source: GRDC, 'Understanding wheat quality', 2009

What is the role of glucose on yeast activity?

What is the role of temperature on yeast activity?

What happens to the carbon dioxide gas when it is heated in the oven?

## Complete a science investigation report

Include Aim, Hypothesis, Variables, Table of Results, Graph, Discussion, Conclusion.

# **10.0 INSIGHT** Wheat quality

There are a number of factors which are used to determine the quality of grain. These include

- Grain hardness
- Grain protein content
- Grain protein quality

To produce a high quality product, the grain received from a farmer must be of high quality. Look at the graph 'Understanding Australian wheat quality'. It shows different classes of wheat from soft to hard; these classes are grades of wheat from different varieties and qualities. Note the relationship with protein percentage. This indicates the protein content required to ensure the optimum performance of a product.

- Breads require between 11.5 and 13.5 per cent protein to ensure the dough retains its strength and elasticity.
- Pasta requires about 14 per cent protein to ensure it retains its shape and structure when boiled.
- Cakes and biscuits require around 8.5 per cent protein only as they do not need the same structural ability as the end product is crumbly rather than chewy or stretchy.

Along the journey from seed to store there are many factors which could affect the quality of the grain grown and received.



### 18 THE SCIENCE BEHIND DOUGH QUALITY

CONSUMER

# Determining the quality of wheat



Did you know?

Wheat protein content is so important to how products look, taste and perform that it is one of the key criteria on which international wheat trade is based.

When wheat is assessed for quality the portion of protein is measured. The protein content is important for determining how well a gluten structure will form in the dough. External factors including soil type, climate and weather relate to how well the grain protein will develop.

## **Protein content**

Grain protein content is largely due to external factors including farm practices such as the addition of fertilisers and environmental impacts, with genetics playing a minor role. Protein content is very important in determining what the wheat will be used for. For example - how will the flour interact with water? Will it form a well-structured dough? Will the action of kneading create the gluten structures to enhance bread texture?

## **Protein quality**

The protein quality within the grain is largely due to the genetic composition of the wheat and how the external environmental factors may affect their expression. Protein quality is measured to understand the formation and properties of the grain's proteins. Measurements include testing dough made from the grain flour for viscoelasticity (stretch) to understand how it will function.

## Label



Which circle below best represents protein content and which represents protein quality?

# 11.0 INSIGHT Understanding proteins

There are twenty common amino acids which act as the building blocks of proteins. Peptides are a type of amino acid characterised by short chains and connected by peptide bonds. Proteins are long chains made up of hundreds or even thousands of amino acids, all joined together by peptide bonds. We can look for the presence of protein in samples with the Biuret Test: a test using a blue copper ion reagent which will interact with a compound with two or more peptides to produce a violet/dark purple hue.



List how many peptides bonds each of the following has and what colour can be expected in the Biuret test if they are present.

AMINO ACIDS	
PEPTIDES	
PROTEINS	

## **The Gluten Protein**

Gluten is a large protein made by the joining of two other proteins: glutenin and gliadin. A flour which is high in protein is high in gluten and therefore desirable for its structure and textural attributes which it gives in baked products. The Biuret Test looks for the presence of peptide bonds and thus proteins. In wheat, we know this protein is gluten.



## How many peptide bonds do you think gluten has and what colour would you expect in the Biuret Test if gluten is present, such as in good quality grain?

GLUTEN				
--------	--	--	--	--

# **12.0 PRACTICAL** The Biuret Test

Gluten is clearly a very important protein! Just like starch, protein quality can be affected by a rainy day. Flour millers and bakers want to know they are getting a grain with good protein quality. Protein content is often measured by using a combustion method which uses a catalyst to reduce nitrogen which in turn represents protein present. A second test is the use of Near-Infrared Spectroscopy (NIR), which uses light to determine the protein content against a reference. For the purpose of this experiment, we will use the Biuret Test which will indicate the presence of peptide bonds, which are the linkages which make proteins.

The Biuret Test uses a reagent made of copper sulfate  $(CuSO_4)$  and sodium hydroxide (NaOH). When peptide bonds are present, remembering such bonds exist in protein, the copper ions will form a complex with the nitrogen atoms of the peptide bonds. When these complexes are formed the solution turns from blue to purple.



## Safety

- Personal protective equipment is required including safety glasses, gloves and laboratory coats or aprons.
- If the solution contacts skin, it can cause irritation. Be sure to wash off immediately.

## Equipment

- Biuret solution
- A: Flour from weather damaged grain
- B: Flour from high quality grain
- Deionized water
- Pipette
- Test tubes
- Test tube rack

## Method

- In a test tube, at a ratio of 5:1 add deionized water to sample A. In a separate test tube, repeat for sample B.
- 2 Add 5 drops of Biuret solution to each test tube. Watch for a few minutes, observing any colour change.
- 3 Record your observations and summarise how these results are reflective of the flour quality.

# **13.0 INSIGHT** The effect of rain on dough...

Wheat proteins such as gluten can be affected by a range of on-farm practices. Some are within the control of the farmer, others are not. A rain at harvest can trigger a series of chemical reactions in the grain which has a detrimental effect on the protein quality and end product.

Take a look at the picture right. Picture 1 shows rain on a mature wheat crop (note the rain droplets on the wheat head, or spike) which occurred in the paddock at harvest time, while Picture 2 shows the potential outcome of this event.

As water comes into contact with the ripe grain, it is absorbed through the scutellum and germination is triggered. Germination triggers a complex series of chemical reactions including enzymatic hydrolysis. This is undesirable and referred to as 'shot grain'.



PICTURE 1



PICTURE 2

(Source: Associate Professor Daryl Mares, University of Adelaide)

Rain damaged grain affects the quality, taste and behaviour of the flour, the dough and the end product!

Annotate the below drawing to show your understanding of the effects of rain on grain.



# 14.0 PRACTICAL Making dough from rain damaged grain

When rain damaged grain is milled to flour and made into a dough, behavioural changes in the dough can be observed. It might be stickier, crumblier, have less stretch, and can even be a different colour. However, the most damage occurs when the dough is baked (heated).

As the temperature increases to more than 60 degrees Celsius the degraded starch granules gelatinize. This means the original crystalline, ordered structure of the starch molecules are lost. This results in the dough clumping together as the molecules are unable to form a structured dough. The proteins such as gluten are also degraded. End products made from weather damaged grain are inferior in colour, appearance and taste – essentially the dough loses its stretch and extensibility (figure 4).

Bread produced from weather damaged grain and high quality grain. Note the differences in colour, appearance, structure and height.



(D.Mares, 2015)

## Equipment

- Grain mill
- Good quality wheat
- Weather damaged wheat

\*\*Note, this is not for human consumption

- Two bowls labelled 'weather damaged' and 'high quality'
- 500g of weather damaged flour
- 500g high quality flour
- 70 80ml water
- 4g salt

### Your challenge is to make two batches of dough:

One out of weather damaged (sprouted grain). One out of high quality (sound wheat) grain.

## Method

Using the grain mill, grind the samples into flour. Make sure to clean the flour mill between grinding each sample to prevent contamination of samples.

Make your bread using the simple bread recipe as follows:

- 250g flour
- 155ml tepid water
- 10g fresh yeast
- 1/2 tablespoons sugar
- 1/4 level tablespoon fine sea salt
- flour, for dusting

- 1 Preheat the oven to 180°C.
- 2 Make a well in the flour then pour in half of the water, then add the yeast, sugar and salt and stir with a fork.
- 3 Gradually mix in the rest of the flour until you form a dough, then add the remaining water.
- 4 Mix... and mix some more. Flour your hands then knead away the dough usually requires about 4 or 5 minutes of good, solid kneading until you have a silky and elastic dough.
- 5 Now you are ready to do the first prove. Round your dough into a nice ball shape then flour the top, place it in a floured bowl, cover with cling film and allow it to prove for half an hour. It should double in size.
- 6 Now take the dough, knock all the air out of it by bashing and kneading it again then shape it as you desire and leave it to prove for a second time for 30 minutes, until it has doubled in size once more.
- Very gently place your bread dough on to a flour-dusted baking tray and into the preheated oven. Don't slam the door or you'll lose the air that you need.
   Bake for 25-30 minutes or until cooked and golden brown.
- 8 Now sit back and watch!! Compare which is weather damaged and which is normal.

## \*\*DO NOT EAT THE WEATHER DAMAGED SAMPLE AS MOULD CAN COME WITH WEATHER DAMAGE!

## Practical questions Making dough from rain damaged grain

1.	Are	e there any immediate differences you notice in:
i	a.	The colour of the flour?
		i. Weather damaged:
		ii. High quality:
I	b.	The way the dough behaved when kneading?
		i. Weather damaged:
		ii. High quality:
	c.	The colour of the dough?
		i. Weather damaged:
		ii. High quality:
	d.	The way the dough behaved throughout the cooking process?
		i. Weather damaged:
		ii. High quality:
	e.	The end product?
		i. Weather damaged:
		ii. High quality:
2.	Wŀ	nich would you eat and why?
3.	Wł	ny is it important to test grain quality at the silo?
4. '	Wł	nat does water trigger in a seed?
5.	Но	w does alpha amylase affect dough?

# **15.0 INSIGHT** Food chemistry

When rain occurs at the time grain is about to be harvested, damage can be caused. As the grain absorbs the water, it begins to swell.

Alpha amylase is then produced and is released into the endosperm.

Alpha amylase is an endo acting enzyme meaning it has the ability to cut large chain molecules into small chain molecules by cleaving internal links. This is called Enzymatic Hydrolysis!

Think of it as a little pac-man that cuts apart the links in the long-chain starch molecules to form short-chain simple sugars which the germinating embryo can then use as a food source.



This is a great process if the seed is in the ground germinating as this reaction is essential to produce simple sugars which the growing seedling uses for food. But it is not so great if the grain is destined for bread making!

## Food chemistry: Alpha amylase, starch and bad bread

## You have probably heard that bread is a 'starchy food'. But what is starch?

During photosynthesis, plants produce food for themselves in the form of sucrose. When the plant has enough food it will store it for later in the form of starch. Starch is a granular storage molecule, produced as a product of photosynthesis and stored in the plant. In corn, wheat and rice, large deposits of starch are stored in the seeds. Starch is made up of two molecules: amylose and amylopectin.

Starch is a carbohydrate – an energy molecule!

Carbohydrates are made of **C**arbon, **H**ydrogen and **O**xygen.

Starch is a polymer of glucose. The molecular formula is (C6H10O5)n, where n can be many thousands.

# **16.0 ACTIVITY** Sugars and enzymes

## Read the following and fill in the blanks.

Carbohydrates, like starch, are grouped into three different types of sugars. They have different classifications depending on how many sugar molecules are linked.

MONOSACCHARIDES	DISACCHARIDES	POLYSACCHARIDES
Single sugar molecule	ls sugar molecules linked	Many sugar molecules linke
e.g. Glucose, fructose, galactose	e.g. Maltose, sucrose, lactose	e.g. Starch, glycogen, cellulo
Have you heard of any of	these sugars before and can you nan	ne a food they are found in?
Have you heard of any of Food containing monosaccharides	these sugars before and can you nan Food containing disaccharides	ne a food they are found in? Food containing polysaccharides
Have you heard of any of Food containing monosaccharides	these sugars before and can you nan Food containing disaccharides	ne a food they are found in? Food containing polysaccharides
Have you heard of any of Food containing monosaccharides	these sugars before and can you name Food containing disaccharides	ne a food they are found in? Food containing polysaccharides

# **17.0 INSIGHT** Enzymes and sugars

There are two types of chemical reactions: physical changes and chemical changes. Physical changes include a change of state (e.g. liquid to solid), separation, deformation or mixing. No bonds or linkages are broken. In a chemical change, bonds are broken and/or reformed. Although you cannot see chemical changes, you can look for evidence that they are occurring. For instance, a colour change, precipitation, or in the case of food chemistry, a change in texture, smell or taste.

Chemical reactions can be the result of a change in temperature, change in surface area or concentration, collision of particles and/or through a catalyst like an enzyme.

Throughout the environment there are different enzymes which can break down different molecules into smaller parts. For example, cellulose, a polysaccharide found in celery, is broken down by cellulase. The human body does not produce cellulase and therefore is not able to digest cellulose. This is why celery does not give us much energy – it is mostly cellulose. However, our body does produce the enzyme amylase in our saliva, meaning that foods containing amylose like bread can be digested.

## Complete the following table

ENZYME	SUBSTRATE
LIPASE	LIPIDS
	AMYLOSE
PROTEASE	

Most enzymes end in 'ase'. They are named by adding 'ase' to identify it as an enzyme, to the substrate that it acts upon or digests.

Let's take a closer look at starch to better understand how enzymes work to break it down.

Starch is made up two polymers: amylose and amylopectin in the form of repeating glucose molecules joined together by covalent glycosidic bonds. Starch is a polysaccharide.

Alpha amylase is an enzyme which is able to digest starch and will cut the amylose and amylopectin at these bonds leaving short simplified glucose molecules. The enzyme has digested the \_\_\_\_\_\_ saccharide into a \_\_\_\_\_\_ saccharide.

What type of reaction do you think this is? Physical change / chemical change (Circle)

What is the cause of the chemical reaction in which starch is broken down?

## The below diagram shows an example section of starch molecular structure. Draw a line where alpha amylase could break these molecules down.



# **18.0 INSIGHT** Catalysts and starch

In biological systems, chemical reactions need catalysts to a) occur or to b) occur at an effective rate

In plants, biological systems include what happens at a micro level. For example, systems of the cell, of organelles, of internal regulation. Enzymes are a catalyst in these types of systems as well as in many other systems which exist in nature and in our body.

## **Enzymes and substrates**

Substrates are the molecules which are undergoing a reaction. The enzyme will bind to the substrate to catalyse the reaction. In the reaction of the polysaccharide <u>starch</u> being broken down to the monosaccharide <u>maltose</u> through *enzymatic hydrolysis*, the acting enzyme is <u>alpha amylase</u>. Use the following diagram to complete the formula for the breakdown of starch during seed germination:



## Factors affecting enzymatic activity

To work effectively, enzymes rely on their shape and structure. External factors can alter this and as a result, the rate at which an enzyme catalyses a reaction changes. These factors include the temperature, pH, concentration of the enzyme and of the substrate as well as inhibitors or activators. For example, as enzymes heat up, they have greater levels of energy meaning the reaction happens quicker. Eventually, there will be less substrate to act upon because of this and the reaction will begin to slow.

## Determining alpha amylase in wheat

When the mature wheat heads get wet from the rain, they begin to germinate and sprout. This speeds up the rate at which alpha amylase is produced, resulting in thousands of these enzymes. Luckily Australia has strict grain quality standards. Grain delivered to silos is assessed for any signs of rain damage. There can be different levels or stages of weather damage. Visual assessments along with grain bulk density measurements and tests for alpha amylase help ensure all the grain destined for food production is top quality. In fact, there is a zero tolerance for weather damaged grain! Imagine having soggy bread or pasta that had no stretch!



# **19.0 PRACTICAL** Testing for starch and the effect of alpha amylase

Alpha amylase is present in weather damaged grain and can degrade starch and cut the long-chain molecules into simple sugars thus destroying the starch. Heat can degrade starch even further as alpha amylase can still be active at 60 degrees Celsius.

Part 1) In this experiment, iodine will be used to test different samples of flour: white processed, whole grain flour made from sound grain and wholegrain flour made from weather damaged grain. Milk will be used for a negative control while starch will be used as a positive control.

Part 2) Secondly, iodine will be added to flour in the presence of heat to measure the effect of heat on enzyme activity.

When adding iodine to a solution, a blue-black colour results if starch is present. If starch amylose is not present, then the colour will remain white. The structure of the amylose molecule is key to this reaction! Amylose forms a spiral structure (like a coiled spring). The iodine molecule slips inside the amylose coil and shows up as the blue black colour.

## **PART 1**

Testing for the presence of starch in different flour samples

## Equipment

- Sample of high quality plain flour (shop bought)
- Sample of whole grain flour
- Sample of weather damaged flour
- Sample of milk
- Sample of starch
- Electronic balance accurate to at least two decimal places
- Grain mill

- 10 mL measuring cylinder and teat pipette
- 6 small test tubes in rack with rubber stoppers
- Water bath heated to 90°C or hot plates with a beaker of water at same temperature
- Paper towel
- Liquid iodine with teat pipette
- Distilled/de-ionised water

## Safety

- · Personal protective equipment is required including safety glasses, gloves and laboratory coats or aprons.



- DANGER: Hot water is used in this exercise. Take care to use heat-proof gloves or tongs when handling hot glassware.
- Liquid iodine is potentially hazardous (note we are using the mild form of Betadine which is a sore throat gargle, this is the safest form for student handling). If any should come into contact with skin, simply wash with water. Do not consume.

## Method

- 1 Take six test tubes and label each one carefully with:
  - a. Milled weather damaged flour
  - b. Good quality flour
  - c. Shop bought flour
  - d. "uncooked" shop bought flour
  - e. Milk negative control
  - f. Starch positive control
- 2 Add 4ml milk to one tube and 0.1g starch to 3ml of deionised water in another test tube.
- 3 Weigh 0.1 g of prepared milled weather damaged flour into test tube one, 0.1 g of good quality flour into test tube two, 0.1 g of shop bought flour into test tube three and 0.1g of shop bought flour into test tube four.
- 4 Add 3mL of de-ionised water to each tube and mix using a spatula until the solution becomes cloudy (about 10-15 seconds).
- "Cook" all samples excluding the one labelled "uncooked" in a water bath at 90°C for 10 minutes, then remove and allow to cool for two minutes.
- 6 Add four drops of iodine to each tube, insert stopper and invert several times to mix.
- 7 Write your results and observations on the activity sheet.

Source: University of North Dakota, 'Enzymes'

1. Explain what happened when you added iodine to the following and indicate why this might have occurred:

a. Uncooked white processed flour:

b. Cooked white processed flour: \_\_\_\_

c. Wholegrain flour made from sound grain: \_\_\_\_

d. Wholegrain flour made from weather damaged grain: \_\_\_\_

2. What are the implications of poor quality starch on bread production?

**3.** Can you think of any innovative ways farmers might manage rain at harvest, e.g. new research or technologies?

4. Explain the difference between wholegrain and white flour? Which is better for you and why?

## PART 2 Testing the effect of temperature on amylase

## Equipment

- Starch
- lodine
- Amylase
- Ice
- Spot plate with many small depressions
- 4 x test tubes
- Dropper
- Pipette
- Timer
- Water bath at 40°C
- Beaker full of ice record temperature
- Beaker with boiling water –
  require Bunsen burner set up

## http://www.und.nodak.edu/dept/ jcarmich/101lab/labshtml/enzymes

Predict what effect temperature will have on amylase with starch.

## Method

- 1 Label each of the four test tubes:
  - a. Ice
    - b. Room temperature (RT)
    - c. 40°C
    - d. Boiling
- 2 Using the pipette, put 3ml of starch into each test tube.
- 3 On a spot plate, add one drop of iodine to twenty-four wells.
- 4 To each test tube add 0.5ml of amylase solution. Put each test tube into their corresponding setting beaker of ice, tube sitting at room temperature, water bath at 40°C, beaker of boiling water. Start timing.
- 5 At two minutes, take a drop from each of the tubes and test for the presence of starch by dropping the solution into a well of iodine on the spot plate. Repeat this for each tube at 10 min, 15mins, 20mins, 30mins recording the results of the iodine test at each.

Source: University of North Dakota, 'Enzymes'

## **Record observations**

Track the results of your experiment by placing a positive (+) or negative (-) mark to indicate whether or not starch is present.

	2 MIN	4 MIN	6 MIN	8 MIN	10 MIN	12 MIN	15 MIN
lce							
Temperature°C							
Room temperature							
Temperature°C							
40°C							
Boiling							

### Which temperatures allowed for complete hydrolysis during the 15 minutes of the experiment?

Discuss your results, including whether or not your prediction was correct.

# 20.0 Good reads

# **21.0 References**

Grains Research and Development Corporation, 'Understanding Wheat Quality', 2009, https://www.grdc.com. au/.../6F94BAEDAAED4E66B02AC992C70EB77 Encyclopedia Britannica, 'Chemical Compound: Polysaccharide', 2015, http://www.britannica.com/science/ polysaccharide

Encyclopedia Britannica, 'Starch', 2015, http://www.britannica. com/science/starch

Marshall University, 'Alpha Amylase', http://science.marshall. edu/murraye/alpha\_amylase.htm

Australian Wheat Board, 'AWB Wheat Quality Fact Sheet: Sprouted Grain', https://www.awb.com.au/NR/rdonlyres/ B835A072-EDB9-4C7A-AD84-323DEDEF66DD/0/Sprouted\_ Grain\_factsheet.pdf

BBC, 'BiteSize: Chemical Digestion', 2014, http://www.bbc. co.uk/schools/gcsebitesize/science/ocr\_gateway\_pre\_2011/ ourselves/1\_whats\_for\_lunch4.shtml

British Nutrition Council, 'Testing Foods for Protein', 2004, http://www.foodafactoflife.org.uk/attachments/d631ae01-38c9-47918f0f5869.pdf

Nuffield Foundation, 'Testing for Starch', 2011, http://www. nuffieldfoundation.org/practical-biology/testing-leaves-starchtechnique

Khan Academy, 'Hydrolysis', 2015, https://www.khanacademy. org/science/biology/macromolecules/carbohydrates-andsugars/v/hydrolysis

ABC, 'Wheat Price Rally on Back of US Wet Weather', McAloon, C, 2015, http://www.abc.net.au/news/2015-06-29/ wheat-prices-rally-on-back-of-us-wet-weather/6580572

Australian Bureau of Statistics, 'Year Book Australia 2012 – Environment:Water', 2012, http://www.abs.gov.au/ausstats/ abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20 Features~Water~279

St Vincent College UK, 'Yeast Activity', 2014, https://vle. stvincent.ac.uk/

Agriculture and Biological Sciences, 'Enzymes in Bakery', 2013, Miguel, A.S.M., Martins-Meyer, T.S., E.V.C., Figueredo., Lobo, B.W.P. and Dellamora-Ortiz., G.M, http://www. intechopen.com/books/food-industry/enzymes-in-bakery-current-and-future-trends

New Zealand Flour Millers Association (2016) The Science of Baking, http://www.flourinfo.co.nz/index.php?option=com\_ content&view=article&id=39&Itemid=53

Blakeney, A.B., Cracknell, R.L., Crosbie, G.B., Jefferies, S.P., Miskelly, D.M., O'Brien, L., Panozzo, J.F., Suter, D.A.I., Solah, V., Watts, T., Westcott, T and Williams, R.M. (2009) Understanding Wheat Quality. A Grains Research and Development Corporation publication viewed online at: https://www.grdc. com. au/.../6F94BAEDAAED4E66B02AC992C70EB77