THE ICC HANDBOOK OF
Cereals, Flour, Dough
& Product Testing
Methods and Applications

EDITED BY
Stanley P. Cauvain
BakeTran, High Wycombe, Buckinghamshire, UK

Assistant Editor
Rosie Clark

DEStech Publications, Inc.
439 North Duke Street
Lancaster, Pennsylvania 17602 U.S.A.

Copyright © 2017 by DEStech Publications, Inc.
All rights reserved

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

Main entry under title:

A DEStech Publications book
Bibliography: p.
Includes index p. 517

Library of Congress Control Number: 2017932594
ISBN No. 978-1-60595-104-1
# Table of Contents

**Preface**  xi

1. **Introduction to Testing Methods and Their Applications**  1
   STANLEY P. CAUVAIN
   The Reliability of Measurements  3
   Expected Standard Uncertainty  4
   Food Safety and Quality Systems  10
   References  12
   Further Information on Testing and Standards  13

2. **The Application of Testing Methods in Cereals Breeding Programs**  15
   L O’BRIEN and R. L. CRACKNELL
   Introduction  15
   Breeding Behaviour and Its Influence on Application of Testing Methods  17
   Factors Influencing Application of Testing Methods  19
   Importance of Experimental Design  20
   General Requirements of Early Generation Cereal Testing Methods  21
   Converting Grain to Flour, Wholemeal or Grits  23
   Pre-treatment of Grain Prior to First Stage Processing  24
Wheat  26
Durum Wheat  32
Barley  32
Testing for Malting Quality  34
Oats  36
Maize (Corn)  37
Some Useful Web Sites  38
References  39

3. Testing Cereals in the Field and at the Store and Its Relevance to End-product Performance  47
Introduction  47
Sulphur  47
Nitrogen  49
Orange Wheat Blossom Midge  50
Fusarium Mycotoxins  51
Amylase/germination Testing  54
Moisture Determination  54
Storage Insects and Mites  59
Mycotoxin Testing (Out-Loading)  60
Grain Condition Post Harvest (In-Store)  61
Conclusion  71
References  71

4. Using Cereal Testing at Mill Intake  77
STANLEY P. CAUVAIN
Introduction  77
Grains Testing at Intake  78
Testing Single Grain Varieties  96
Testing Agreed Specifications  97
The Test Milling of Grains  99
Organic, Spelt and Other Ancient Grains  101
Durum Wheat  101
Conclusion  102
References  103
## Table of Contents

### 5. Applications of Testing Methods in Flour Mills . . . . 107

STANLEY P. CAUVAIN

Introduction  107

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>An Outline of Grain Milling Processes</td>
<td>108</td>
</tr>
<tr>
<td>Testing Wheat Flour Milling Stocks During Production</td>
<td>112</td>
</tr>
<tr>
<td>Checking the Final Flour</td>
<td>117</td>
</tr>
<tr>
<td>Testing Wholemeal Wheat Flours</td>
<td>130</td>
</tr>
<tr>
<td>The Modification of Wheat Flour</td>
<td>131</td>
</tr>
<tr>
<td>Additions to and Fortification of Wheat Flours</td>
<td>135</td>
</tr>
<tr>
<td>Analysing Animal Feeds</td>
<td>137</td>
</tr>
<tr>
<td>Malted Wheat and Barley Products for Foods</td>
<td>138</td>
</tr>
<tr>
<td>References</td>
<td>139</td>
</tr>
</tbody>
</table>

### 6. The Relevance of Testing to the Manufacture of Bread and Fermented Products . . . . . 143

STANLEY P. CAUVAIN

Introduction  143

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Synopsis of Common Breadmaking Processes</td>
<td>143</td>
</tr>
<tr>
<td>Dough Processing from Divider to Prover</td>
<td>147</td>
</tr>
<tr>
<td>Expansion in the Prover and Structure Setting in the Oven</td>
<td>148</td>
</tr>
<tr>
<td>The Relationship Between Flour Properties and Bread Quality</td>
<td>149</td>
</tr>
<tr>
<td>Testing Rye Flours</td>
<td>166</td>
</tr>
<tr>
<td>Test Baking</td>
<td>167</td>
</tr>
<tr>
<td>Bread Flour Specifications</td>
<td>168</td>
</tr>
<tr>
<td>Assessing Bread and Fermented Product Quality</td>
<td>169</td>
</tr>
<tr>
<td>References</td>
<td>173</td>
</tr>
</tbody>
</table>

### 7. The Relevance of Testing to the Manufacture of Biscuits (Cookies), Cakes and Pastries . . . . . 177

STANLEY P. CAUVAIN

Introduction  177

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Synopsis of Biscuit (Cookie) Making Processes</td>
<td>177</td>
</tr>
<tr>
<td>The Relationship Between Flour Properties and Biscuit (Cookie) Quality</td>
<td>180</td>
</tr>
<tr>
<td>Biscuit (Cookie) Flour Specifications</td>
<td>184</td>
</tr>
<tr>
<td>Assessing Biscuit (Cookie) Quality</td>
<td>186</td>
</tr>
</tbody>
</table>
A Synopsis of Cake Making Processes 188
The Relationship Between Flour Properties and Cake Quality 189
Cake Flour Specifications 190
Assessing Cake Quality 191
A Synopsis of Pastry Making Processes 193
The Relationship Between Flour Properties and Pastry Quality 194
Pastry Flour Specifications 196
Assessing Pastry Quality 196
Test Baking for Biscuits, Cookies, Cakes and Pastries 198
References 200

8. Cereal Testing in the Manufacture of Extruded Products 203
ROBIN C.E. GUY
Manufacture of Foods Using Extrusion Cooking Technologies 203
Raw Materials Used to Manufacture Extruded Products 205
Chemical Analysis 206
Physical Analysis of Raw Materials 207
The Assessment of Products 210
Physical Methods for Assessing Products 211
Chemical Analysis 214
Physical Texture Analysis 215
Sensory Analysis 215
References 216

JOHN R.N. TAYLOR and KWAKU G. DUODU
Introduction 219
Maize 219
Sorghum 228
Millets 236
Rice 238
Oats 245
Useful General References 249
References 250
## Table of Contents

### 10. Testing for Food Safety

ROLLAND ERNEST POMS

Introduction 257

Use of Mycotoxin Analyses 259

Acoustic Testing for Deoxynivalenol (DON) in Wheat Grains 269

Rapid Testing for Food Safety in Cereals and Flour: Gluten and Food Allergens 284

The Occurrence of, and the Analysis for, Pesticide Residues in Cereal Grains and Processed Cereal Products 292

### 11. Testing for Animal Feed Production

EVA MARIA BINDER, PETRA HUBMAYER and GEORG MITTERER

Introduction 305

Testing for Microbiological Contaminants in Animal Feed 306

Agricultural and Other Chemicals 311

Mycotoxins 314

Conclusion 320

References 321

### 12. The Relevance of Testing to the Manufacture of Asian Noodle Products

LARISA CATO

Introduction 329

Classification of Asian Noodles 330

Quality Requirements for Asian Noodles 331

Methods for Testing Noodle Quality 332

Summary 339

References 340

### 13. Cereals Testing Equipment

Introduction 345

Brabender® GmbH & Co.KG 345

CHOPIN Technologies® 371

Elementar Analysensysteme GmbH 395

Perten Instruments AB 402

Stable Micro Systems 426
Table of Contents

C-CELL: Bakery Products Imaging System 456
Megazyme 458
R-Biopharm AG 465

   Introduction 467
   ICC Standard Methods 468

Index 517
Preface
The International Association for Cereal Science and Technology (ICC)

FIRST called the International Association for Cereal Chemistry (ICC), ICC was founded in 1955 on the occasion of the Third International Bread Congress in Hamburg with its main objectives being to develop and standardize investigation methods for cereal grains and cereal-based products (ICC, 2015). Today these objectives remain at the centre of the ICC’s functions to which has been added the development of international cooperation and the dissemination of information related to cereal science. A non-political, non-religious and non-profit-making organisation the ICC offices are based in Vienna, Austria, where the Secretariat is run by Ms Michaela Pichler.

ICC’s strength lies with its excellent international network and contacts with cereal scientists in the many fields of study related to cereal grains. Since its inauguration the ICC has been at the forefront of method standardisation and new method development and now has over 200 standard methods, recommended and rapid methods. Through its working groups and international networks the ICC continues to examine and introduce new standard methods for application to cereal grains. In that task it works closely with other standardisation bodies, such as AACC (American Association of Cereal Chemists) International and other international bodies to work towards the harmonisation of existing and new methods.

A key role for the ICC has been and continues to be to provide a forum for the exchange of information and cooperation in the cereal science field. It does this through sponsored scientific meetings such as the International Cereals and Bread Congress (held every four years in
different parts of the world), through its involvement and promotion of many international conferences and workshops, and through its coordination and project-based activities. Important examples of the continued relevance of ICC are its significant involvement with the MoniQA Network of Excellence, previously coordinated by ICC and funded by the European Union with the aim of the international harmonization of analytical methods for food quality and safety assessment, the ICC-led Task Force on Mycotoxins and Sampling and the Healthgrain Forum.

For more information on the ICC, its activities, standard methods and publications visit: www.icc.or.at.

As part of its continuing involvement improving food quality and safety, the ICC has an agreement with Wageningen Academic Publishers for the regular publication of Quality Assurance and Safety of Crops and Foods. QAS, as the journal has become known, is available 6 times per year, and publishes research and review papers associated with the quality and safety of crops. It targets plant-based primary raw materials, their harvesting, storage and conversion to human foods.

QAS has a strong focus on the development and application of new analytical tools and their potential for quality assessment, assurance, control and safety. The scope also includes issues of risk assessment, traceability, authenticity, food security and socio-economic factors.

For more information and to subscribe to QAS go to: www.wageningenacademic.com/journals/qas.

Reference


Acknowledgements

I wish to acknowledge the major contribution made by the late Linda Young, my fellow co-editor on the first edition. In addition to the contributors identified as authors for the different chapters I wish to acknowledge help with information on Malted Wheat and Barley Products from Simon Wooster, Edme, UK, the Fluoroscan from Aytun Erdtung, Branscan Ltd., UK and Published Testing Methods and procedures from Dr Meinholf Lindhauer, ICC Technical Director. I also wish to thank Rosie Clark for her diligence in pursuing the various contributions and her support in preparing text and illustrations for this second edition.
Introduction to Testing Methods and Their Applications

STANLEY P. CAUVAIN

The cereal taxonomic family comprises wheat, triticale, rye, barley, oats, rice, maize, sorghum and millets. Within each member of the cereal family there are many species and varieties which have found use as both human and animal food. New varieties are being bred and added to the list on a regular (annual) basis. Many of the new varieties are designed to deliver improved and very specific characteristics for agricultural purposes. Such characters as disease resistance, stress resistance (e.g. drought resistance) and yield are high on the list of desirable properties for the cereal breeder. Equally important are the end-use performance characteristics of the cereal grain but they have probably received less attention from breeders and growers than the agricultural traits until relatively recently in the development of new cereal varieties. In part this is because much of the historical emphasis on developing new cereal varieties has been driven by the need to increase the basic food supply and this still remains a key requirement in many parts of the world. However, in areas where the supply of cereals exceeds the demands of basic nutrition there is inevitably more opportunity to place greater emphasis on delivery of those quality traits which are more closely linked with the quality of the end product.

As cereals are traded on a global scale the needs for appropriate and standardised quality testing methods are significant. Historically the evaluation of grain was carried out in a largely subjective manner. Obvious problems of grain dampness and spoilage would have been relatively easy to see and agree (hopefully amicably) between supplier and user. There is no doubt that the experienced miller and baker could make some sort of prediction about milling and baking quality with a form of crushing test—probably achieved by chewing a small sample of the grain or a small test milling. In this scenario agreement between supplier and user as to the ultimate performance of cereal grain and the flour obtained from it would certainly have been harder to achieve.
Even today in some parts of the world farmer, miller and baker or brewer can have diverging opinions on the quality attributes of grains grown in a particular location because, despite the advances of cereal science, it remains hard to predict the ultimate performance of the basic raw material. In part this is because of the wide variety of uses to which cereal grains are put by human-kind. Not only do they provide food for animals but also food and drink for humankind (more recently cereal grains are being viewed as a source of fuel energy though such uses are outside the scope of this book). With such a diversity of end-uses and potential products it is inevitable that different testing methods have evolved to assess the quality of the raw material and it is with this complexity in mind that the concept of this book developed.

The objective of the contributions in this book is look closely at the applications of cereal testing methods from the differing points of view in the ‘grain chain’, starting with the cereal breeder and ending in the bakery, brewery and animal feed compounder. Each contribution considers a range of available testing methods for their applicability in a given set of circumstances. It is not the intention of the work to identify the ‘best’ or the ‘right’ way to test cereal grains in a particular environment rather, to consider what is available and how it might be applied. The same cereal test may well be referred to in several places throughout this book and this reflects the way in which the determination of a particular cereal grain characteristic may be used in different ways in different parts of the grain chain. It is also not the intention of contributors to be unduly critical of existing methods though it is inevitable that there will be recognition that nature of the results from some existing testing methods may still require a high degree of expert interpretation to make them genuinely ‘useful’.

It is in the nature of cereal science that research and technology change the type of information that we require and so it is also inevitable that new methods will evolve for the testing of cereals. The challenges facing the cereal scientist when evolving new testing methods are significant. For example, consider the manufacture of bread in which the special properties of the gluten developed during dough mixing are readily appreciated when the dough is mixed and processed by hand. The baker can feel the changes which occur as first the proteins hydrate and the gluten network gradually begins to develop and change. Dough consistency and properties of elasticity and extensibility could be readily evaluated using fingers and with experience the rheological properties of the dough could be linked with the final food product. So ingrained is this need to evaluate gluten quality in dough that even today experienced bakers working in large automated plant bakeries will take the opportunity to take a small piece of dough to feel and stretch. They can always tell you whether the dough feels ‘right’ or ‘wrong’ but when pressed can seldom tell you what it is they are assessing or looking for.

It was inevitable that the application of science to the natural world during
The 19th century would lead to studies on the processing and use of grains and these examinations form the basis of the cereal testing methods that we know today. In developing objective methods for the evaluation of grains and the flours produced there were a number of clear, mainly chemical, tests which could establish quality characteristics. Less clear would be how to define those characteristics that related mainly to the performance of the flour in the ultimate manufacturing environment, e.g. the bakery or brewery. In this case a series of mainly physical tests evolved many of which were related in some way to more abstract sensory properties, for example gluten quality.

Historically the standardisation and publication of testing methods suitable for application to grains has been carried out by organisations like the International Association for Cereal Science & Technology (ICC), the American Association of Cereal Chemists (now AACC International), the American Oil Chemists Society (AOCS) the International Organisation for Standards (ISO) and national standards bodies. However, while the publication of such standardised methods has ensured their dissemination around the world there is no collective work which considers the applications of cereals testing methods to the various stages of the transition from wheat grain to final product. It is important to recognise that many of the international methods used today started out as a ‘locally’ preferred means of evaluating grain and products quality before attaining international acceptance. Often there is no perfect predictive test for cereals at any stage of processing and it is inevitable that new ideas will be introduced in an effort to improve our ability to manufacture foods from grains. By including new ideas in this book we hope that we will continue to stimulate the development of new testing methods, some of which may eventually make the transition to that of approved ‘standard method’.

The Reliability of Measurements

In order for analytical data to have value users must be confident that the values that they are given have both relevance and meaning for their particular needs. Confidence in analytical data comes from using accredited service providers with methods developed and approved by appropriate national and international bodies. As discussed above the ICC has been pre-eminent in the development and publication of standard methods relevant to the use of cereal grains and many of the standard methods will be referred to in subsequent chapters.

Confidence in measured values comes with an understanding of what is actually being measured and the reliability of the data. Many analytical techniques used in cereals-related testing do not measure fundamental properties of materials, or indeed use fundamental units. In the cereals industry the mea-
measurement of protein is one such example in that analytical techniques measure nitrogen and interpret the value in terms of protein with two different factors, one for human and one for animal feed. It is also very important to recognise that no analytical measurement is without error and there are a number of potential sources of errors which need to be considered when making comparison between the materials being tested and the methods being used.

In order to help the reader in the discussions which follow in subsequent chapters some relevant definitions are given which attempt to place measured values which may be quoted into their appropriate analytical and applications contexts.

**Expected Standard Uncertainty**

This term is associated with analytical validation and the performance of a particular method. Rose et al (2011) considered that “The standard uncertainty associated with a method is a single parameter that gives an estimate of the combined effect of the individual factors that describe the method on how far we can expect a measurement result to lie from a true concentration”.

**Accuracy**

This term refers to the precision of data or closeness of estimates to the exact or true values of the property that was measured and as such it reflects the degree to which the information provided correctly describes the phenomena that is was deigned to measure. It includes providing the results of the assessment of source data for sampling and non-sampling errors and may be decomposed into bias (systematic error) and variance (random error).

**Measurement—Sources of Error**

There are a number of potential sources of error in analysis. These include those associated with sampling, sample preparation and analytical error. Obtaining ‘relevant’ samples for testing is one of the major challenges facing the grains industry.

**Reliability**

In statistical terms reliability is viewed as the closeness of the initial estimated value(s) to the subsequent estimated values.

**Repeatability/Reproducibility**

These two terms are sometimes viewed as having the same meaning in statistical terms; being defined as ‘The concept that survey procedures should be repeatable from survey to survey and location to location; the same data
processed twice should yield the same results’. In cereal testing the two terms have tended to be given slightly different, though clearly related meanings.

**Repeatability**
Repeatability is a measure of the ability of single instrument to give the same reading on the same sample at different times of testing.

**Reproducibility**
Reproducibility measures the degree of agreement in readings between different laboratories using the same type of instrument on the same samples.

**Standard Error**
Defined as ‘The positive square root of the variance of the sampling distribution of a statistic’ it includes the precision with which the statistics estimate the relevant parameter as contrasted with the standard deviation that describes the variability of primary observations.

**Ring and Proficiency Testing**
In the establishment of an accepted standard method it is important that the method is robust, reliable and able to deliver meaningful results. A key part in the establishment of a standard method is the conducting of a ‘ring test’. This requires collaboration between a number of laboratories, each of which is equipped to carry out the analysis concerned. The participating laboratories have access to appropriate samples from an agreed central source. After the various analyses have been completed the individual results will be collated and analysed to provide relevant precision data which usually become part of the standard method. If there are problems in agreeing the precision of the data it may be necessary to carry out further ring tests with fresh samples.

The principles and processes associated with the statistical analysis of results from collaborative studies in ring tests are discussed in detail in ICC Recommendation No. 203.

The establishment of a standard method is not the end of the analytical process. Laboratory expertise may vary with time through changes in laboratory personnel and equipment performance. In order to ensure that data from a given laboratory remain accurate and relevant it is common practice to engage in some form of proficiency testing using centrally supplied materials (e.g. AACC International Check Sample Series).

**Sampling**
The evaluation of a batch of any raw material, processed material or product relies on the evaluation of small numbers of samples being taken from the batch and the assumption that the sample will be representative of the batch.
Thus, sampling is one of the most, if not the most critical step associated with testing. The application of sampling practices is discussed in more detail in subsequent chapters, here it is just necessary to introduce the concept and comment in general and some of the key issues and practices.

**Laboratory Data**

The largest part of grain evaluation and testing data will be obtained through measurements made off-line in the laboratory where trained staff and carefully controlled environments can be found. These conditions ensure a high degree of precision and reliability associated with the measurements. These are ideal circumstances in which to carry out testing for quality control and research purposes though it should always be borne in mind that such evaluations are not always being made under the conditions in which the material will be used. This is especially true for flours which are utilised in baking processes.

The value of testing data for quality control purposes is to ensure that the raw material has been manufactured to an agreed specification. This should not be confused with the prediction of the ultimate performance in a given manufacturing process. The specification should have been previously agreed on the basis of understanding that the raw material will deliver the required final product quality and what variations to a given parameter value can be tolerated. To achieve this situation a common understanding between supplier and user is required.

In the research environment laboratory data are commonly used to investigate relationships between raw material properties and processing requirements and final product quality. Laboratory-based research studies offer opportunities for insights which can improve process efficiencies, optimise final product qualities and lead to new developments. Once again it is not common to carry out such studies under typical processing conditions and care must be taken over the interpretation of data with respect to practical conditions.

**At-line and On-line Measurements**

In view of some reservations expressed above with respect to laboratory-based data there appears to be a powerful case for measurements to be made at the production line, ideally on-line. These are not easy tasks for a number of reasons.

Firstly, many of the measurements require highly specialised equipment not best suited to the environments which are typical of many processing sites. Often the tests involve the passage of some period of time before the results are available and so do not lend themselves to providing data which might be used in ‘real time’ to adjust process recipes or operating conditions; there are a few exceptions which are further discussed below.

Perhaps the major drawback for at-line or on-line testing remains the appli-
cability of the testing method. As noted above (and will be discussed in detail in later chapters) many cereal analytical methods are ideally suited to quality control purposes. Historically cereals testing methods have (with a few exceptions) been based on the analysis of some core chemical properties or a form of ‘quality’ evaluation using a mixture of flour and water. The latter includes possibly the easiest way to assess flour protein content and quality but few wheat flour-based products comprise a simple mixture of flour and water.

Thus far the most effective on-line measurements in the grains industry has been the application of near infra-red (NIR) measurements to wheat and the flour produced from it. Indeed many wheat flour ‘certificates of analysis’ are based purely on NIR data. However, a cautionary note is that many flour properties included in the output from NIR measurements have been calibrated against some form of standard reference which in themselves are not robust fundamental measurements and therefore the data can be prone to misinterpretation. A note to ‘Use with care’ should be included in the assessment of the data, at least in the users mind if not on the C of A.

The development of increasingly sophisticated image analysis techniques does in the case of final products provide opportunities for true on-line measurement and data collection. Bread height, hamburger bun shape and crust colour are now relatively easy to achieve on-line, at least in larger industrial bakeries. The challenge (further discussed below) is to how to link process data with raw material analysis.

**Test Baking and Similar Small-scale Quality Assessments**

The link between raw material qualities and final products has been traditionally established through test baking or by mimicking key processes on a small scale. Many different test baking methods exist which for example reflect the variety of breadmaking methods employed around the world (Cauvain, 2015a). Test baking plays a significant role as a potential quality control function and a research tool but given the wide variety of baking methods employed cannot be seen as an absolute predictor of bread making performance. For example, evaluating the breadmaking potential of wheat flour using a pan bread test does not necessarily reflect its potential for baguette production. Major challenges of using small-scale assessments such as test baking are associated with the problems of scale-up and batch processing times. Never the less small-scale quality assessments often come closest to predicting performance in ultimate processing. They are of course, time-consuming and should be carried out in a controlled environment such as a laboratory.

**Using Test Data**

As noted above, common uses of test data include the facilitation of grain trading and quality control functions. In many cases the use of test data as a
means of predicting ultimate performance relies on the ‘expert’ interpretation of the data. This is a perfectly reasonable approach as human beings are good at ‘pattern matching’. Essentially an expert will view the pattern of information in the analytical data of a raw material, or groups of raw materials, and match this to performance patterns based on their experience. Commonly experts develop a set of heuristic rules (sometimes referred to as rules of thumb) which enable them to predict the direction of change without necessarily being able to quantify the magnitude of change. A simple example, could be the increase in the protein content of a wheat flour which would be expected to lead to an increase in bread volume or height while recognising how great the increase will be depends on the dough recipe and processing conditions, such as mixing.

The adjustment of recipe and processing conditions to compensate for variations in raw material qualities has traditionally been the province of the expert or less reliably, has been determined by ‘trial and error’ during processing. With the increasing industrialisation of processes such as breadmaking tolerances for variations in product quality become smaller and the need for stronger and more reliable processing models linking raw materials and product qualities increases. Inevitably this leads to the consideration and application of mathematical models.

A specific problem for the development of mathematical models for grain processing technologies is the large number of interactions that occur in the transition from grain to final product. This is particularly true of breadmaking where final product quality depends on a myriad of ingredient-recipe-process interactions. Given the complexity of grain processing to final product, it is not surprising that mathematical modelling has tended to concentrate on narrow sections of the transition; that way they are easier to model but the challenge remains that such narrow models still have to be integrated into a more holistic model which could describe the whole process.

**Gathering and Using Data in a Commercial Context**

The significant advances in computing power has made the capture of data in commercial environments an increasingly feasible option. Today many pieces of equipment used in commercial operation have the capacity to continuous record and the potential to download data which are important in commercial operations. One such example is the recording of individual dough piece weights in commercial bread bakeries, in some cases to ensure that final products will meet any point-of-sale legislation but in all cases to optimise dough yields from a given batch and process efficiencies in general.

While process data may be gathered on a regular basis it is not necessarily true that it is stored and used effectively in commercial contexts. Part of the challenge of gathering data in a commercial context is the sheer quantity that
becomes available and the need for large data storage capacities; until recently it has not been common practice to even consider the provision of data storage, let alone detailed and integrated analysis.

If the data storage capacity is available the next issue to consider is what data to collect. Many cereal processing systems are batch fed even if the subsequent processing is continuous (e.g. wheat bins to the break rolls or dough batch to the dough divider). Also a significant period of time elapses from the moment the raw material first enters the process to the moment that the final product leaves. This requires that data will need to be related to a fixed time line in order to facilitate effective analysis. For example, the rheological properties of a batch of dough may be assessed some 2-4h before the subsequent bread qualities can be measured.

The analysis of very large data batches very quickly has now become possible as a result of the increases in computing power. Specialist analysis programs do exist in non-food industries which allow the visualisation of complex industrial processes on a continuous time related basis though there are few instances of their application to cereals grain processing. With increased automation of industrial scale processing their application will increase.

**Future Challenges for Testing Methods and Their Application**

The challenges facing the development of new testing methods, improving existing methods and their application are many.

They include the following:

- The continued development of rapid testing methods, especially in the area of food safety. Examples of possible applications are discussed in subsequent chapters.
- Improvement to the limits of detection and the reliability of measurements. Again, many of these will be related to food safety but in some cases such improvements can be a ‘double edge sword’ so that as the limits of detection are pushed ever lower, questions over what are ‘safe limits’ for contaminants become increasingly important.
- Increasing development and application of at-line and on-line testing methods designed to be used in the field prior to or at harvesting, as well as subsequent grain storage and processing to final products.
- Opportunities for on-line analysis which can be linked with improved process control to improve process efficiency, reduce energy requirements and minimise waste.
- The development of material testing methods with greater predictive ability, commercial relevance and practical applications. In the laboratory this may, for example, be associated with a move towards using more commercially relevant recipes while in the production environment
this may be the development of easy-to-use methods for plant operatives. A number of tests already exist which can be used to assess final product quality in a plant environment but their application is limited and because they are carried out at the end of the manufacturing process they do not provide information for real-time control of manufacturing operations.

- Improvements to predictive models which link raw materials qualities with recipe and processing information. For grain-based processed foods this remains a significant challenge because of the large number of complex interactions involved but equally the potential rewards are significant.

**Food Safety and Quality Systems**

Cereals food quality may be encompassed under two general headings; technical quality which is aimed at delivering a consistent product that consumers will enjoy and products that are safe to eat and will not cause consumers any harm. When references are made to quality systems the most common expectation is that of ensuring food safety though the principles by which manufacturers deliver safe food may be equally be applied to the delivery of products of consistent quality and as such may be addressed using commonly applied systems such as Hazard Analysis Critical Control Points (HACCP) and Good Manufacturing Practice (GMP).

HACCP (Wallace and Mortimer, 2000) is extremely effective as a tool in delivering safe food products and is based on identifying and assessing potential hazards and then establishing control systems that implement preventative measures. This focus on preventative measures is designed to stop hazards entering the food chain rather than relying on time consuming and expensive end-product testing. The implementation of HACCP which looks at individual stages of the food processing chain still requires that food safety checks by way of raw material and sample analysis be carried out. A key practical benefit of implementing HACCP can be a significant reduction in raw material and product testing but it does not eliminate risk. Regular, on-going reviews of HACCP should be undertaken, not least in response to potential new hazards.

GMP (Manning, 2013) is commonly used alongside HACCP with perhaps a greater emphasis hygienic practices in relation to the handling of raw materials and their processing into food. Eliminating the potential for food spoilage microorganisms is of course, as much about delivering safe food as the elimination of foreign bodies and chemical contaminants. Where perhaps GMP and HACCP both differ and overlap is the nature of the hazard which is being assessed and the measures which need to be put into place to limit or eliminate
that hazard. In addition to GMP one sees Good Agricultural Practices (GAP) and Good Hygienic Practices (GHP).

HACCP, GMP and the like are increasingly being used in international trade and the movement of raw materials, intermediates and final products. Such procedures are essential in the global nature of food market places today and this may mean that standards applied in one part of the world are demanded in another where the interpretations of ‘acceptable’ practices differs from that of the final market place. This is particularly true for the many major food retailers that directly provide food to consumers. In some cases the standards which the retailer imposes on their supplier may even exceed those which apply locally or in a specific region. In some ways one may argue that major retailers have become guardians of public health, not least because in these days of instant information exchange food retailers cannot afford the negative publicity which food safety scares quickly attract.

There are other techniques which can be applied to delivering efficient process control and which will make a significant contribution to consistent production. In this short introduction it is only the intention to provide brief comments on the overall concepts involved food quality systems. An all-embracing term which might be applied to processes involved in the provision of consistent quality and safe food might be Total Quality Management (TQM). Many of the tests, techniques and procedures which will be discussed in detail in the following chapters form the basis of the tools which are essential to the operation of TQM but to be effective they need to be used in a structured environment. While their application to raw materials and finished products are commonly seen as the responsibility of the Quality Control or Technical Departments, their effective implementation is the responsibility of all those involved in food production. It is now common to see statements which describe Quality Systems in terms of “farm to fork” and “plough to plate”. Such descriptions are intended to show the need for integration of quality systems from the growing of raw materials right to the arrival of the final product with the consumer. However, a critical examination of many such systems shows (rightly) a strong emphasis on food safety, though perhaps without the same rigorous consideration of technical manufacturing constraints and final product. Ultimately you can have the safest food in the world but if it does not also have the consistent qualities sought and purchased by consumers it has no value to anyone involved in the food production chain.

In much the same way that HACCP seeks to eliminate or minimise the risks of food safety TQM seeks to eliminate or reduce risks associated with product quality defects; i.e. loss of quality attributes which would mean that the product does not reach consumer expectations. In modern manufacturing environments high productivity at minimum costs and minimal (zero) defects are the ideal. However, meeting those manufacturing expectations are not so
easy when dealing with ‘natural’ raw materials. No matter how well controlled agricultural practices are, the impact of geography and the environment will play a major role in determining the suitability of raw materials for processing into human food. In this context the cultivation of wheat is a classic example of the challenges facing growers and users of the raw material. Each harvest delivers a raw material which will be subtly different from the previous harvest and so significant attention has to be paid to the assessment of raw material in the sense of it suitability for end use.

To achieve this quality testing methods have to be put into context with the recognition that wheat will be used to make a wide range of products each with its specific quality characteristics and employing a wide range of processing methods. Even after many years of study an inescapable conclusion is that there is no single quality testing method which can predict sufficiently well the performance of a given variety or parcel of wheat in the food factory. Most of the quality data which is gathered during wheat and flour testing requires further interpretation by human experts to ensure that concepts like TQM are met. It has been argued that wheat and flour testing data are at best indicative of end performance rather than predictive (Cauvain, 2015b). Some of the potential challenges for cereals testing methods and their application have been noted above.

References


Further Information on Testing and Standards

There are a number of internationally recognised bodies engaged in the development of cereal testing methods, they include:

The American Association of Cereal Chemists—AACC International—www.aaccnet.org
The American Oil Chemists Society—AOCS—www.aocs.org
The International Association for Cereal Science and Technology—ICC—www.icc.or.at
The International Standards Organisation—ISO—www.iso.org
Secretariat of the Codex Alimentarius Commission, Joint FAO/WHO Food Standards Programme—www.codexalimentarius.net
European Food Safety Authority—www.efsa.europa.eu
Moni QA—www.moniqa.org

There are also national bodies who are also engaged in such activities (e.g. BSI in the UK, CEN in France) and they will be linked to an appropriate international body, commonly ISO.
Index

AACC International, 3, 5, 13, 16, 23, 346, 371
Accuracy (definition), 4
Acidity determination, 480
Acrylamide, 257, 259
Aflatoxin, 259, 260, 269, 271, 273, 274, 315
Air-jet sieve, 125
Allergen testing, 288
Allis Chalmers mill, 24
Alpha-amylase activity, 93, 95, 121, 124, 157, 166, 180, 221, 235, 413, 460, 461, 474, 475, 482, 484, 504, 510 inhibition by silver nitrate, 414
Aluerone, 110, 117
Alveoconsistograph, 382, 498
Alveograph, 98, 100, 156, 162, 182, 185, 195, 378, 386, 495
Amino acids, 96, 221, 235, 289, 482, 494, 511
Amylograph, 166, 227, 242, 358, 361, 366, 496
Amylopectin, 23, 31, 207, 220, 231, 239, 332, 414, 460
Amylose, 23, 31, 127, 133, 207, 220, 243, 460 determination, 221, 245
Andreasen Pipette method, 477
Animal feeds heavy metals, 311, 312, 508 microbiological contaminants, 306, 465
Barley (continued)
    malting, 16, 20, 22, 23, 25, 34, 54, 138
testing, 20, 22, 96, 249, 407, 418
quality, 79, 236, 415
processing, 111
Benzoyl peroxide, 132
Besatz (see also Grain screenings), 80, 83, 101, 470, 471, 478
Beta-amylase, 157, 235, 463
Beta-glucan, 249, 460
determination, 461, 464
in malting, 407
in oats, 246
Biscuit, 24, 156, 177, 178, 181, 215, 368, 394
brittleness, 187, 444
dimensions, 186
dough, 178
    consistency, 178, 180, 182
    firmness, 183, 430
hardness, 417
thickness, 186
wedging, 186
Biuret method, 28
Blackpoint, 69, 79, 80
Bohlin VOR, 184, 190
specks in white flour, 69, 113
Bread, 2, 7, 19, 21, 30, 52, 93, 98, 109, 126, 132, 159, 161, 170, 173, 269, 293, 351, 411, 417, 458, 502, 505
    cell structure, 147, 157, 166, 213
    crumb softness, 136, 182, 430, 432
    firmness, 172, 429
    flavour, 171
toughness, 432
    volume, 8, 119, 147, 153, 390, 454
Breakfast cereal, 203, 208, 212, 259, 293, 414, 424
    bowl life testing, 441
    recipe, 206
Brioche, 411
Bulk density of
    extruded products, 212
    grains, 37, 61, 83, 210, 222, 276
Bunt, 69, 80
Bushel weight (test weight), 22, 61
C-Cell, 170, 191, 211, 456
Cadmium, 311, 508
Cake, 25, 95, 98, 107, 119, 188, 408, 418, 458
cell structure, 171, 190
crumb softness, 191, 417
flour particle size, 124, 189
high ratio, 124, 133, 189
Calcium fortification, 120, 133, 137, 206
Carbon dioxide, 144, 148, 157, 162, 177, 379, 391, 397, 399, 472
Carotenoids, 120, 490
Catalase, 95, 121, 509
Celiac disease, 285
CIE colour, 22, 28
Chorleywood Bread Process, 146, 151, 163
Clathrates, 215
Coeliac disease, 513
Coliform testing, 306
Cone penetrometry, 187
Consistograph, 382, 385, 498
Corn, 15, 18, 23, 27, 31, 37, 203, 206, 211, 219, 227, 269, 273, 279, 297, 365, 376, 380, 415, 421, 423, 509, 513, 515
    breakage, 24, 223
Crop assurance, 59
Crust, 173, 191, 259, 429
    character, 169, 417, 458
    colour, 7, 169, 170, 479
Damaged starch, 29, 113, 117, 121, 124, 149, 157, 181, 332, 382, 392, 462, 483, 498
    in mill fractions, 112
De-branning of wheat, 109
Diastatic activity, 34, 139, 234
Dietary fibre (see also Fibre), 126, 128, 246, 461, 486
DigiEye, 214
Differential scanning calorimetry, 173, 243
Dioxins, 311, 312
DNA, 17, 31, 35, 38, 309
Dobraszczyk-Roberts dough inflation system, 159, 427, 439
Dockage, 80, 470
DON, 51, 53, 265, 315, 320
acoustic testing, 269
Dough, 8, 16, 23, 26, 29, 32, 47, 357, 416, 430, 433
development time, 30, 123, 152, 154, 164
softening, 93, 145, 151, 154
stickiness, 63, 160, 434, 435
testing, 30, 159, 162, 439
doughLAB, 154, 195, 402, 409
Dried gluten addition to wheat flour, 118
Dumas protein, 25, 28, 89, 118, 288, 396, 472
Durum, 17, 25, 32, 98, 101, 260, 375, 385, 387, 390, 404, 406, 420
gluten quality, 407
pigmentation, 113, 490
sedimentation test, 91, 481
vitreousness, 22, 418, 474, 478
Dynamic oscillation, 159

*E. coli* (see Coliform testing)
Electrophoresis, 30, 96, 480
Electronic noses, 80
ELISA, 53, 267, 274, 285, 289, 310, 319, 465
activity, 29, 33, 34, 95, 121, 138, 166, 234, 248, 362, 406, 490, 509
additions to biscuit dough, 179
Ergot, 61, 67, 80, 247, 315, 316
Equilibrium relative humidity, 192, 447
Expected standard uncertainty, 4
Experimental design, 20, 24
Extensional strain hardening, 159
Extended Craft Knife, 427, 444, 446
Extensograph®, 30, 100, 155, 162, 185, 195, 346, 358, 494
Extrusion cookers, 203, 205
Falling Number, *see* Hagberg Falling Number
Fat, 138, 147, 177, 188, 192, 220, 285, 311, 346, 402, 411, 420, 424, 489
FAPAS®, 290, 318
Farinograph®, 30, 100, 130, 150, 162, 181, 195, 346, 353, 358, 387, 410, 479, 495
Farintom, 102
Fibertec™, 128
Fibre, 36, 130, 151, 210, 390
determination, 207, 420, 461, 486
dietary, 126, 246, 486
Filth test, 125
Fluoroscan, 116
Foliar urea, 49
Ford cup, 184, 190
Free amino nitrogen, 235
Fructan assay, 461, 462
Fumonisins, 260, 315–317
Furans, 311
*Fusarium*, 51, 60, 68, 264, 269, 315
Gas
chromatography, 245, 312, 511
production, 93, 136, 148, 157, 390
retention, 136, 144, 148, 157, 162, 189, 386, 390
German rolls, 164
Glutomatic System, 92, 402, 407, 473
Gluten, 29, 98, 100, 111, 114, 118, 132, 143, 166, 178, 204, 284, 513
content, 91
development, 2, 134, 148, 177, 183, 193, 330
index, 32, 92, 111, 473, 474
intolerance, 285
testing, 90, 358, 366, 377, 388, 407, 409, 433, 448, 472, 473
turbidity test, 111
Glyphosate, 292–395, 297, 299, 302
GMP, 10, 11
Grade Colour Figure, 113, 115, 149, 181
Grain
bulk density (*see also* Specific weight and Bushel weight), 84

*Index*
Grain (continued)

- conditioning, 25, 85, 100, 108, 110, 349, 373, 419
- counting, 84, 228, 241
- drying, 38, 57, 64, 88, 110, 223, 239, 265
- moisture content, 25, 37, 49, 54, 61, 83, 86, 94, 100, 110, 222, 227, 265, 295, 376, 419, 475, 476, 479, 510
- N:S ratio, 48
- screenings, 65, 80
- sorting, 80
- storage, 9, 58, 70
- Grain storage pests, 70
- Grains broken, 63, 209, 223, 239, 419
- heat damaged, 64
- sprouted, 63, 81
- Granule Bound Synthase genes, 31

HACCP, 10, 258, 266, 286
- Hagberg Falling Number, 54, 62, 93, 98, 100, 108, 121, 124, 136, 149, 166, 180, 402, 406, 474
- effect of Orange Blossom Midge, 50, 70
- Heavy metals, 312, 508
- Hectolitre weight, 61, 98, 419, 421
- High performance liquid chromatography, 314, 318, 509
- High-resolution gas-chromatography, 312
- High-resolution mass-spectrometry, 312
- Immuno-affinity columns, 319
- Inframatic, 420
- Infraneo®, 372, 376
- Insect traps, 59
- Intake testing, 101
- Junior flour mill, 20, 24
- Kett Pearlest tester, 86, 237, 241
- Kieffer rig, 427, 433
- Kjeldahl protein, 25, 28, 118, 207, 288
- Kramer shear cell, 215, 427, 446, 448, 450–452
- Lab-on-a-chip, 97
- Lateral flow devices, 53
- Lead, 311
- Light cabinets, 333–334
- Lignin, 36, 127, 207, 486
- Limits of detection, 9, 320
- quantification, 299
- Lipase, 136, 249
- in cake batters, 190
- in oats, 248
- Lipids, 17, 95, 215, 241, 388, 490
- analysis in extrusion, 206
- Lipoxygenase, 32
- Liquid chromatography-mass spectrometry, 317, 319
- Load extension tests, 183
- Lost embryos, 64
- Lovibond Comparator, 139
- Malting, 16, 20, 32, 34, 54, 94, 138, 234, 238, 407, 415, 418
- Malt, 20, 23, 32, 35, 139, 234, 238, 362, 406, 414, 461, 474, 491, 514
- extract, 16, 33, 36, 139, 236
- diastatic power, 34, 234
density, 222
dent, 220
fermentability, 225
flint, 220
grits particle size, 208
grits hardness, 209
hardness, 84, 224
lime cooking, 226
masa, 227
moisture content, 420, 475, 479, 510, 513
popcorn, 37, 220, 228
Maize (continued)
porridge, 227
stress cracks, 223
vitreousness, 223
waxy, 220
white, 220
yellow, 220
Mercury, 311, 313, 505
Mepiquat, 295, 297, 299, 302
Microbiology, 125, 307, 512
of wheat, 82
plating methods, 308
Micro Visco-Amylo-Graph®, 365
Millet, 1, 219, 232, 236, 475, 476, 513
malt, 238
Mixing tolerance index, 154
Mixograph, 29, 152, 162, 181, 228
Mixolab, 154, 164, 371, 382, 387, 499
Mixolab Profiler, 389
MoniQA, 13, 257, 258
Moisture content
determination, 25, 37, 54, 87, 114, 419, 475, 476, 510
grinder effects, 56
temperature effects, 56
Moisture meters, 54
overall accuracy, 57
Moisture migration in pastry, 196
Moisture probes, 57
Munsell colour system, 170
Mycotoxin (see also Fusarium), 37, 51, 60, 68, 82, 108, 125, 259, 269, 465
analyses, 259
in animal feed, 288, 314
testing, 60, 263, 317
Nicotinic acid, 485, 486
networks, 90, 425
NIT, 23, 26, 32, 35, 38
Nitrogen, 4, 25, 34, 47, 91, 235, 396
application to grain, 49
determination
by Dumas, 89, 396, 472
by Kjeldhal, 89
bran, 246
groats, 36, 246, 249, 407
milling yield, 247
Ochratoxin A, 58, 60, 257, 260, 264, 315, 320, 508
On-line measurements, 6, 108, 113, 116, 169
Orange wheat blossom midge, 50, 70
Organic grain, 101
Ottawa compression cell, 215, 441, 450
Pan bread, 7, 28, 93, 151, 169, 408, 410, 418, 429
Particle hardness in extrusion, 209
Particle size index (PSI), 27, 86, 404
Particle size of wheat flour, 24, 56, 85, 89, 97, 100, 124, 130, 181, 185, 189, 331, 403, 477, 512
analysis, 27, 124
bran, 113, 115
in extrusion cooking, 208
rice flour, 209
Pasta, 98, 329
colour, 32, 120, 490
quality, 25, 101, 113
testing, 387, 407, 417, 445, 447, 450
total organic matter, 481
Paste rheology, 194
Pastry, 193, 437
crispness, 193, 445
laminated, 193, 438
short, 193, 196
Pathogen testing, 310, 465
Pathogenic bacteria, 83
PCR, 97, 101, 287, 307, 310, 465
Pearling index test for grain hardness, 27
Pekar test, 113, 114
Pelshenke, 29, 91
Penetrometer, 184, 427
Pentosan, 29, 111, 166, 181, 362, 393, 434
Pericarp, 116, 220, 223, 226, 229, 236, 245
Peroxidase, 95, 121, 221, 249, 466, 509
Index

Perten diode array, 152, 420
Pesticides, 50, 59, 292, 295
  in animal feed, 311, 313
  testing, 293, 297
Passport Scheme, 125
pH of flour, 133
Pheromone traps, 50
Phol farinator, 102
Polychlorinated biphenyl (PCB), 311
Polymerase chain reaction, see PCR
Polyphenol oxidase, 29, 32
Polysaccharides, 246, 249, 458, 464
Proficiency testing, 5, 290, 295–296, 318
Prolamins, 285, 512, 514
Protein, 16, 29, 47, 64, 91, 134, 166, 221,
  231, 285, 331, 382
  analysis in extrusion, 207
  content, 118, 121, 124, 130, 149, 181,
  185, 396, 471, 472, 482
  of grain, 16, 21, 25, 28, 36, 49, 89, 97
  of mill fractions, 112, 114
  quality , 26, 29, 34, 119
Puroindoline, 30, 31

Quadrumat mills, 20, 99, 346–349
Quality systems, 10
QTLs, 17, 20, 31, 36

Radio immune assays, 319
Rapid Visco Analyzer, 228, 483
Reducing agents in biscuits, 136, 182
Reliability, 3, 4, 9
Repeatability, 4, 5, 54, 276, 290, 511
Reproducibility, 4, 5, 269, 277, 290, 430,
  511
Resistant starch, 127, 462, 486
Rheofermentometer, 158, 390, 392
Rice, 207, 238, 259, 286, 297, 330, 390,
  404, 415, 419, 421, 475, 480, 493,
  510, 513
  amylose content, 244
  aroma, 245
  colour, 242
  elongation ratio, 244
  flour, 208
  fissuring, 241
  gel consistency, 243
  (continued)
  gelatinization temperature, 242
  hydration, 244
  kernel dimensions, 239
  milling quality, 238, 240, 241
  processing, 238
  texture, 244
  types, 96, 239
  RIDA, 465, 512, 514
  Ring testing, 5
  Risk analysis testing of grain, 52
  Rodent droppings, 67, 71
  Rye flour, 144, 166, 347, 362, 482, 496
  water absorption determination, 355
Saccharose, 489
Salmonella spp., 306
Sampling, 5, 21, 47, 55, 59, 78, 306, 372,
  468
  for mycotoxins, 262, 267, 269, 318
  Scoring systems, 335, 458
  SDmatic, 122, 371, 392, 498
  SDS-PAGE, 30
  Sedimentation tests, 124, 477
  SDS, 29, 91, 151
SeedCountTM, 80
Sensory evaluation, 171
  Asian noodles, 332
  Single Kernel Characterisation System
    (SKCS), 22, 26, 35, 85, 209, 418
  SKB units, 139
  Solvent retention capacity, 29, 181, 393
Sorghum, 228, 286, 404, 407, 419, 492
  bleach test, 230, 493
  fermentability, 233
  germinative energy, 491
  grain colour, 229
  grain density, 231
  hardness, 231, 232
  malt, 234
  Sour-dough, 144, 355, 514
  Sources of error, 4
  Soya flour in extrusion, 204
Specific density of extrudates, 210, 212
Spaghetti Flexure Rig, 427, 447, 449
Specific weight (see also Hectolitre
  weight), 61, 83, 98, 372
SpecMan™, 90
Spelt, 101
Spread test, 185
SPX Speck Expert, 113
Squeeze test, 171, 430
Standard error, 5, 277
Starch, 16, 31, 34, 134, 166, 225, 227, 239, 330
    analysis in extrusion, 206
    analyzing content, 207, 221, 420, 461, 488, 489
    in extrusion, 203
    gelatinization characteristics, 36, 133, 166, 189, 242, 358, 364, 387, 412, 482, 483, 496, 497
    swelling volume, 31
Tₘ, 204
    waxy, 31, 220
Statistical analysis, 5, 511
Stenvert hardness tester, 223
Straight-run (wheat) flour, 109, 112
Strain, 159, 184, 190, 386, 411, 439
Stress, 30, 150, 159, 184, 195, 386, 440, 448, 499
Strong-Scott barley pearler, 86
Stirring Number test, 95, 413, 482
Sulphur applications, 47
Swelling index, 29

Tannins, 229–231, 235, 237, 493
Test baking, 7, 126, 478
    biscuits, 198
    bread, 167
    cakes, 199
    pastry, 196, 199
Test milling, 1, 82, 99, 349, 377
Test weight (see also Bushel weight), 16, 22, 33, 36, 83, 98, 222, 231, 247
Texture Analyzer, 197, 234, 238, 244, 416
Texture profile analysis, 172, 338
Thiamine, 487–488
Three-point bending test, 187, 444
Trinexapac-ethyl, 295, 299
Tristimulus testing, 115, 120, 139, 170, 191, 210, 214, 220, 336
Thousand kernel weight, 276

Tortilla/pastry burst rig, 427, 437, 438
Total quality management (TQM), 11
Trichothecenes, 315, 318, 319
UDY dye-binding, 28
    Cyclone mill, 237
Viscograph, 361, 364, 497
Viscosity, 94, 134, 159, 166, 177, 189, 204, 227, 247, 346, 362, 388, 393, 412, 440, 482, 496
    batter, 184, 190
Volume measurement, 169, 191, 210, 415, 454
Warburtons dough stickiness test, 161, 435
Water activity, 83, 192, 196
Wedging of biscuits, 186
Wheat, 7, 26
    bug-damaged, 96, 121, 385
    conditioning for milling, 25, 85, 100, 110, 349, 373, 419
    drying, 88
    genotype, 16, 31
    grading systems, 98
    processing, 113
    waxy, 31
Wheat flour, 26
    additives, 135
    bleaching, 131
    chlorination, 133
    colour, 115, 131
    fortification, 120, 135
    grade, 116, 132
    heat treatment, 134
    specifications for
        biscuits, 184
        bread, 149, 164, 168
        cakes, 190
        pastries, 196
    water absorption capacity, 122
    whiteness, 109
Wholemeal, 23, 100, 109, 135, 261, 294
    flour testing, 26, 130, 353, 363, 408, 474, 481, 490, 496, 499
    test milling, 86, 100, 350
X-ray tomography, 210, 213
Xanthophylls, 131

Yeast testing, 157, 390
Yeasts, 307, 504, 506

Yellow stick traps, 50

Zeleny, 29, 91, 377, 477
Zearalenone, 51, 315, 319