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Traditional European Breads

An Illustrative Compendium of Ancestral Knowledge and Cultural Heritage

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Preface

Bread is one of the most widely consumed staple foods in the world and one of the oldest forms of processed foods, with evidences of bread-like food remains and fermentation utensils developed by our ancestors dating back to the Neolithic era in multiple locations around the world, including Europe and Asia, and the oldest evidences of bread production discovered dating back 4000 years before this Neolithic period. The process of bread-making has been gradually and constantly improved, aiming to adapt to the new demands and changes in preference of the population and to improve the efficiency of the processes and expand the distribution of the products. Not only that, but wide varieties of breads have also been developed over the centuries in multiple countries to incorporate in their recipes special seeds, cereals and other ingredients that were locally produced in these regions, as well as seasonal ingredients produced in these agricultural regions. This led to the development of a wide variety of products (i.e. variable shapes, colours and sensorial profiles), all of them commonly referred to as "bread", that could be consumed with different types of meals on a day-to-day basis, as well as speciality breads associated to particular seasons or even products tightly linked to different festivities, celebrations and religious rituals all over the world. All these traditions and know-how of both bread-making process and bread were developed over centuries in different countries, and even specific geographical areas within the same country, reflecting cultural differences and commonalities between human populations that can also be linked to other food consumption preferences.

This book was originally born from the ambition and interest of the members of the network SOURDOMICS (COST Action 18101 – *Sourdough biotechnology network towards novel, healthier and sustainable food and bioprocesses*) and the project expanded beyond this network to multiple researchers that developed valuable contributions when compiling the current knowledge on the rituals, traditions and recipes of ancestral processes of bread-making in multiple countries in Europe. This book includes multiple figures, pictures and illustrations that are not easy to access or not compiled currently in any other manual in relation to the history and tradition of both bread and/or bread-making processes. This includes pictures and illustrations related to bread-making process, including primitive ovens, tools and products that are currently exhibited in various museums in different countries that exemplify the differences in the ways of living and traditions in different European countries. Furthermore, each chapter also provides the readers with detailed scientific and technological background on these bread-making processes and information on consumer trends in different countries that can be used to evaluate the current situation and future market scenario for bread and bread-related products across Europe.

The book starts with a first chapter, conceptualized by one of the editors, summarising briefly the history of bread-making, bread and bakery products globally; reflecting also on the wide variety of shapes, flavours and tastes of bread and the current "know-how" and scientific literature explaining the complex reactions (physical, chemical and microbiological reactions) that occur at various stages of the bread-making process for the creation of some of the most widely consumed types of bread globally. Moreover, the chapter also covers the current technologies and scientific developments to improve several stages of the bread-making process that allowed the intensification and widespread production of bread and the expansion of shelf-life of the products that allowed an increase in exports and global consumption of several breads. Following this initial chapter, the book continues by describing different aspects of bread-making, traditions and beliefs associated with this product, as well as market trends, current consumption, recipes and research of different varieties of bread produced and consumed locally in various European countries. Each of these 17 chapters, developed by researchers and experts in the field of food science, focused on the bread-making processes and bread products and traditions of one country and/or region, covering in the present edition the contributions of authors from the Baltic countries (Estonia, Latvia, Lithuania), Bulgaria, Croatia, Cyprus, Germany, Greece, Hungary, Italy, Latvia, Malta, Poland, Portugal, Romania, Spain, Turkey and Ukraine.

The readers of this book will discover the history and evolution of bread, a current and ancestral staple food product that developed alongside the human race, resulting in a wide variety and range of interesting traditions and ways of bread-making that were preserved and passed on through generations in different countries and that led to the current wide variety of clearly distinctive products locally produced in different regions in Europe. Intriguing associations and beliefs associated with the process of bread-making and consumption, including myths, religious rituals and oral traditions in different regions, mix in this book with scientific knowledge on the changes occurring in flour for the creation of different bread products. A book in which tradition mixes with scientific knowledge and ancestral know-how that is passed on from generations and still pervades in different regions, coming to the present to enrich our knowledge and understand the present and future direction of this food product that will forever be linked and continue to evolve together with the humankind.

I hope the science and stories curated in this book can help to preserve and keep these traditions, myths, legends and products alive, so future generations can discover, enjoy and benefit from this ancestral knowledge.

Dublin, Ireland Marco Garcia-Vaquero
January 2023

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Chapter 1
The Fundamentals of Bread Making: The Science of Bread

Rahel Suchintita Das, Brijesh K. Tiwari, and Marco Garcia-Vaquero

1 Introduction

Bread in its countless forms is considered as one of the most widely consumed staple foods by humans (Cauvain and Young 2007). The most commonly perceived variety of bread is prepared by heating a shaped and molded dough formed by kneading and mixing cereal flour, typically wheat flour, with water, salt, and a leavening agent mainly yeast which is universally used as the chief biological leavening or rising agent in bread manufacture. The role of yeast in bread is to ferment sugars in the flour into small amounts of ethanol and most importantly, carbon dioxide gas (CO_2) that causes the dough to rise during baking. During baking the bread acquires their characteristic crumb and crust. The crust appears as a continuous, compact envelope developed around the bread during baking operation, and the crumb is characterized by a cellular structure (Della Valle et al. 2012). An essential component of bread is the formation of gluten, a process which does not occur in other bakery products, such as cakes, to any significant degree (Cauvain and Young 2006). Most biscuits and pastries also have limited gluten formation compared to bread

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products. In laminated products, gluten formation is encouraged to some extent and bakers use a specialized layering technique to incorporate fat but without disrupting the gluten (Cauvain and Young 2007). Dewettinck et al. (2008) has decribed bread as a fermented confectionery product produced primarily from wheat flour, water, yeast, and salt by a series of processes involving mixing, kneading, proofing, shaping, and baking. Certain types of bread are manufactured with a chemical leavening agent such as baking soda instead of yeast and some without any leavening agent which do not rise and appear flat. Moreover, varieties of bread of different sizes, shapes, flavors, textures, prepared from diverse ingredients, processed under different conditions exist across many continents (Zhou and Therdthai 2006).

The wide variety of shapes, flavours and taste of bread and multiple procedures for the production of this product is currently considered a "know-how" preserved and maintained for generations mainly as part of their oral tradition, but also art and traditional artifacts that were still maintained and used in rural areas or private households as seen in the multiple chapters of this book focusing on the traditions related to bread across all European countries. As the science evolves, the complex processes of bread making and the differences in the process of bread production, that enable the bakers to produce such a huge variety of clearly distinguishable products, have been investigated and in most cases elucidated. This chapter summarises the science behind bread making and the complex reactions, including the physical, chemical and microbiological reactions, that occur in most cases simultaneously at various stages of the bread making process in several bread varieties. Due to the wide varity of breads in Europe, but also around the globe, this chapter also emphasises the main disoveries in bread manufacturing and the opportunities to bring the traditional know-how of different breads in Europe at industrial scale by the use of several technological aids and scientiffic improvements.

2 Brief History of Bread Consumption

Bread has been stated to be one of the oldest, if not the oldest 'processed' food. In its earliest forms bread would have looked quite distinct from how it is available in modern times, post industrialization (Cauvain and Young 2007). Traditionally the production of bread was mainly linked to fully fledged agricultural population of the Neolithic period in Europe and southwest Asia. However, the recent discovery of charred food remains at Shubayqa 1 by Natufian hunter-gatherers in northeastern Jordan (see Fig. 1.1), empirically dates the production of bread-like foodstuffs to 4000 years before Neolithic agriculture emerged in southwest Asia (Arranz-Otaegui et al. 2018).

The effort taken by our ancestors to improve the digestibility of the wild grass seed precursors of early wheat varieties, by cooking or baking stands testimony to a great step in the evolution of food production by mankind. They comprehended the unique ability of the proteins in wheat to form a cohesive mass of dough after crushing the grains and wetting it followed by subjecting the mix to the mechanical energy of kneading. The formation of this cohesive mass has been attributed by

Fig. 1.1 Picture of the site of Shubayqa 1 showing the oldest fireplaces on the site with bread-like remains. (Image taken from Arranz-Otaegui et al. (2018) originally published by PNAS)

scientists and bakers to the protein 'gluten' developed in wetted wheat flour during kneading which has the ability to trap gases produced by fermentation leading to dough expansion during baking. Gradually through the portals of evolution, the actions of wild yeasts and portions of old dough which is now referred as the starter or mother dough were acknowledged that ultimately paved the way for production of specialized bakers' yeasts we use today. Over the centuries, bakers from every corner of the world have crafted and experimented with traditional bread varieties using their hard gained experience to achieve appreciable bread quality. In recent times, scientific studies and technical advancement have catered to provide efficient, faster and more cost effective ways of bread production that can be integrated with the traditional recipes of craft bakers to satisfy consumers' demand for fresh, wholesome and palatable products as well as to maximize profits of the bread manufacturing industries (Cauvain and Young 2007). Recently, the market report "Bread market – growth, trends, and forecasts (2020–2025)" (Mordor Intelligence 2020) estimated that the global bread market is projected to register an annual growth rate of 1.43% during the period, 2019–2024 as bread dough is a versatile matrix that can be derived into a wide variety of products after processing. Traditionally, bread has been perceived as a staple food, with a ubiquitous consumption worldwide and with time there has been an increased demand of multiple varieties of ethnic breads and whole-meal, multigrain breads, with oats, bran, seeds, etc. Moreover, the bread manufacturers are also promoting the production of regional bread specialties to diversify their products, with fortified, clean label and organic breads being amongst the most demanded bread types amongst health conscious consumers.

3 Types of Bread

There are innumerable varieties of bread around the world with multiple and differentiated characteristics, such as those made from different grains, breads including diverse ingredients and also products produced through varied techniques to avail for multiple shapes and sizes. However, in general bread can be broadly classified into 3 main types (El Sheikha 2015).

3.1 Yeast Breads

These breads are leavened by yeasts and have medium-high rise or volume. The gases released by yeast fermentation get entrapped in the dough which develops a sponge-like microstructure when baking, with air cells enclosed by walls with starch granules embedded in a fibrillar gluten matrix. Yeast breads are eaten globally and most significantly by people in the United States, Canada, and many European nations. White pan bread is the most common variety, but others are gaining commercial popularity crossing the geographical boundaries of their countries of origin. Baguette (French bread), brioche (French buns), Boule (French bread), ciabatta (Italian white bread), Michetta (Italian bread), Challah (Jewish braided bread), Bagel (Polish/ Jewish ring shaped bread), Kugelhopf (Austrian and French bread), Bara Brith (fruit bread of Wales), hamburger and hot dog buns, croissants, sourdough and loaves such as whole wheat, cracked wheat, pumpernickel, rye, and rolled oats, are few examples of yeast bread (Callejo 2011; Chapman 2012; Di Monaco et al. 2020; El Sheikha 2015; Hayakawa et al. 2010; Schlegel-Zawadzka et al. 1933; Wilder 1933).

3.2 Flat Breads

Flat breads may be yeast leavened or unleavened and they have lower specific volume than that of pan bread (Gocmen et al. 2009). They are prepared using batters or kneaded dough and are easily mixed and quick to cook. Flat breads include tortillas (Mexico); Jewish matzah; crepes and crepe like chickpea flour bread (France); dosas, chapatis and parathas (India); Mandarin pancakes and scallion bread (China); okonomiyaki (Japan); pita bread and Lebanese wrapper bread (Middle East) and many varieties crackers. Pita and Lebanese wrapper breads are made from yeasted dough and flattened to rise before baking (El Sheikha 2015).

3.3 Quick Breads

Most quick breads contain baking soda and/or baking powder, to make them rise. They can be made quickly through simple steps. Quick breads include quick loaves such as corn bread or banana bread, muffins, biscuits, coffee cakes, scones, pancakes and waffles (El Sheikha 2015). Today consumers are progressively cosmopolitan in their taste for bread influenced by international travel and cultural exchanges, leading to a broader acknowledgement of the endless varieties of bread. In Europe, for instance, Italian ciabatta, Indian chapattis and French baguette are eaten along with sliced pan bread (Cauvain and Young 2007).

4 The Process of Bread Making

With time, the global market has been flooded with a plethora of bread varieties and thus, multiple bread making processes, almost all of them with the common objective of converting raw flour into a leavened food product mostly via fermentation have been practised. The standard process of bread making to produce pan or loaf-type bread includes major sequential operations described below (Cauvain and Young 2007).

4.1 Sieving Flour and Other Dry Ingredients

This process aims to eliminate any extraneous matters and coarse particles. Moreover, this process also contributes to partially incorporate air and make the flour more homogeneous and free of lumps (Patel et al. 2019).

4.2 Weighing Ingredients

Weighing of different ingredients is carried out as per formulated recipe in appropriate ratios. The formulation for bread varies from bakery to bakery depending on factors such as the cost of ingredients and consumer preference with respect to quality of bread. Salt, sugar, flour improvers, such as oxidizing agents, are added in solutions; while yeast is added as a suspensions (Bhatia 2016). Generally shortening and salt are added after the clean-up stage to reduce the dough mixing time as the sequence in which ingredients are added influences the dough characteristics (Khetarpaul 2005).

4.3 Mixing Ingredients and Dough Formation

The mixing process aims to uniformly distribute all the ingredients to allow the development of gluten in the dough, thus having optimum physical characteristics, with respect to elasticity, resistance to deformation, extensibility, viscosity and stickiness of the dough (Cauvain and Young 2007). All of these factors will influence the pore structure of the bread (Therdthai and Zhou 2014). When the ingredients are mixed with water, hydration occurs at the surface of the flour particles due to the mechanical energy input provided through progressive mixing. This combined action of hydration and continued mixing leads to the gradual formation of the gluten network in the dough depending on the applied shear and elongation forces during the mixing process. Conventional mechanical mixers generally deliver combined deformation flows through blending, stretching, combining, pushing, compressing and folding the dough (Therdthai and Zhou 2014). At a chemical level, mixing allows the polymerization and cross-linking of proteins present in the wheat flour (glutenin and gliadin), generating a 3D structure or gluten network characterized by the oxidation of their sulfhydryl groups (-SH) and cross-linking and re-arrangement of previously existing disulfide bonds that will impart the strength of the dough (Ortolan and Steel 2017). An image of the chemical changes due to the formation of gluten and the microscopic appearance of the gluten network are represented in Fig. 1.2.

The dough system on further mixing becomes more cohesive forming a visco-elastic mass with elastic and viscous properties generally attributed to glutenin and gliadin, respectively (Xu et al. 2007). Excessive shear and mechanical energy due to continued or excessive mixing beyond this stage will cause break-down of the reasonably stable molecular interactions between gluten-forming proteins, depolymerization of large gluten aggregates and disruption of the dough network (Hamer et al. 2009; Bhatia 2016). However, under-mixing may cause small unmixed patches that interfere at the later proofing stage (Rosell 2011). Other effects that occur during mixing involve the incorporation of air that will be essential to provide oxygen for the processes of oxidation and yeast activity. Moreover, this air will generate gas bubble nuclei for the carbon dioxide that will be released by yeast fermentation and the gluten network will prevent the losses of carbon dioxide gas during baking (Cauvain and Young 2007).

The process of mixing can be performed industrially using multiple equipments which are able to mimic a hand-mixing action of compressing and stretching operations (kneading) at high speed, reducing the time of this operation to only few minutes (Marsh and Cauvain 2007). Few of the commercial equipment commonly used at this stage include low speed, spiral (allow both fast and slow speed mixing) and high speed mixers (planetary, horizontal and continuous type mixers).

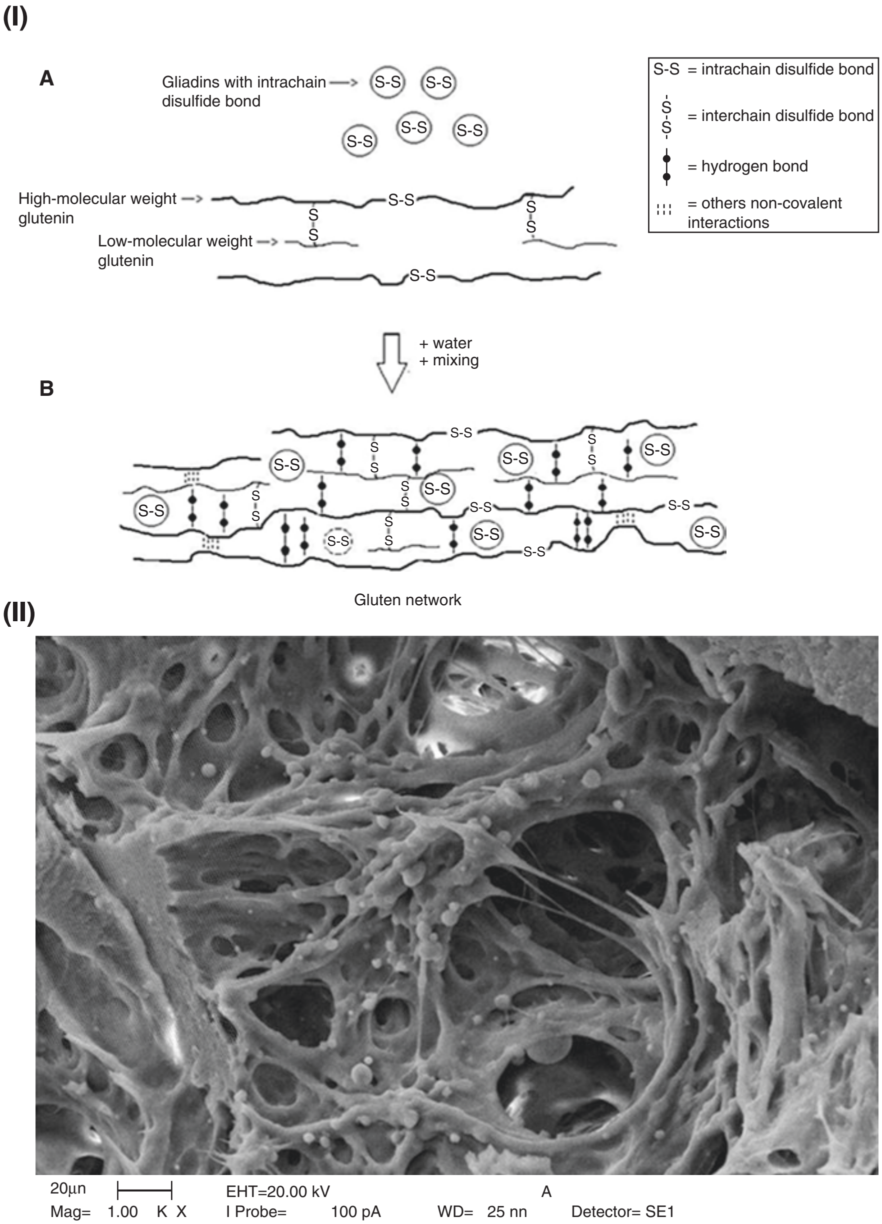

Fig. 1.2 Image of the molecular interpretation of gluten network and the effects of water addition and mixing (**I**) and a scanning electron micrographic image of the gluten network (**II**). (These images were published by Ortolan and Steel (2017) and reproduced with permission from John Wiley and Sons)

4.4 Fermentation Process

The mixed dough should be fermented for a suitable length of time to obtain a light aerated porous loaf of bread (Rao 2017). Fermentation is achieved by adding yeast cultures *(Saccharomyces cerevisiae*) or other cultures, such as lactic acid bacteria (LAB) in case of sourdough, at an appropriate ratio and mixed in the dough (Struyf et al. 2017; Teleky et al. 2020). The key role of the yeast in bread-making is acting as leavening agents. The enzymes in the flour and yeast breakdown starch to sugars which are then fermented by the yeast, primarily to CO_2 and alcohol, and small amounts of glycerol and various compounds (alcohols, esters, aldehydes and organic acids) that contribute to the flavor and aroma of fermented bread-dough (Struyf et al. 2017). The CO_2 gas bubbles produced during fermentation leavens the dough into a foam structure that when baked will generate the aerated structure of bread-crumb (Dobraszczyk et al. 2005).

The leavening process relies on sufficient gas-production that will be influenced by the availability of soluble, fermentable sugars, and on the retention of that gas in the dough that will depend mainly on the amount and properties of the dough (Stear 2012). The fermentation process will depend on multiple parameters with a variable time estimated in 2–6 h or even longer depending on the concentration of yeast added, method of baking and variety of flour used (El Sheikha 2015). The temperature and relative humidity conditions are critical for yeast activity with temperatures ranging from of 30–35 °C and relative humidity of 85% and higher ensuring good yeast activities, while above 40 °C the yeast's performance decreases. The optimum pH range for yeast is 4–6 and below pH 4 the yeast activity begins to diminish and it is inactivated below pH 3 (Bhatia 2016). Presence of nutrients in the form of vitamins and essential mineral compounds also affects the activity of yeast (Broach 2012). The process of fermentation produces multiple and interlinked chemical and physical changes that can be appreciated microscopically in the dough (see Fig. 1.3).

The changes appreciated during fermentation include:

1. Hydrolysis of starch to simpler sugars, that will be then fermented by yeast. The enzyme diastase present in wheat flour begins to breakdown starch in the flour to maltose. Maltase enzyme converts maltose into glucose, invertase enzyme transforms any added sucrose into glucose and fructose and zymase complex converts the glucose and fructose, in the absence of oxygen, to carbon dioxide gas, alcohol and other flavor and aroma organic compounds (Kamel and Stauffer 2013; Rao 2017). The release of CO_2 is accompanied by the growth of air bubbles previously incorporated during mixing and the alcohol will mainly evaporate during baking (Rosell 2011).
2. Lactic acid bacteria produce acids from sugars, subsequently lowering the pH of the dough from 5.5 to 4.7 (Rao 2017), as recorded in sourdough (Teleky et al. 2020).
3. Proteolytic enzymes from flour and yeast also contributes to increase the extensibility and elasticity of the gluten, helping in the retention of gas as the gluten network will expand without rupturing (Rao 2017).

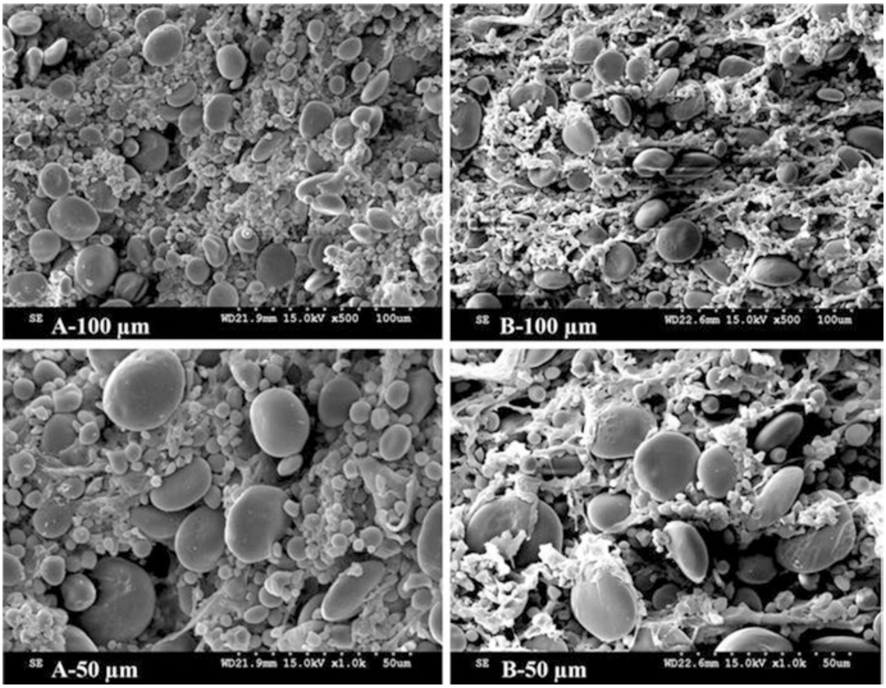

Fig. 1.3 Physical changes in the dough due to the effect of *Saccharomyces cerevisiae* at the beginning (**a**) and end (**b**) of the fermentation stage of dough. (The images were published by Zhang et al. (2018) and reproduced here with permission from Springer Nature)

4.5 Knock Back or Re-mixing of Dough

Kneading or remixing of the dough facilitates expulsion of large gas bubbles and re-dispersion of gas forming smaller, more regular and uniformly distributed bubbles within the dough (Hutkins 2008; Rosell 2011). Punching or knock back of dough in between the fermentation periods enhances the gas retaining capacity of the dough (Kumar 2018).

Knock back also helps in (1) the equalisation of the temperature throughout the dough which assures more uniform proofing, (2) the redistribution of yeast cells and nutrients such that more substrate is available to the yeast for fermentation (Hutkins 2008); and (3) the incorporation of atmospheric oxygen to stimulate yeast activity and the mechanical development of the gluten by the stretching and folding action. The accurate time for the first punch is usually determined by inserting the hand into the dough, withdrawing quickly and observing the behaviour of the dough. If the dough reshapes itself, it is ready for the first punch. This point is normally reached when 60% of the fermentation time is completed (Rao 2017).

4.6 Dough Make-Up

The operations constituting dough make-up aims to transform the fermented bulk dough into appropriate molded dough portions which when baked after final proofing yield bread with desirable properties (Bhatia 2016). This stage involves multiple operations:

4.6.1 Dividing (Scaling)

The bulk dough is divided into uniform individual pieces of predetermined weight and size depending on the final weight of the bread required. Generally, 12% extra dough weight is taken to compensate for any baking loss. Dividing should be done quickly to ensure uniform weight and to prevent any change in the density of the dough due to the produced CO_2 which may cause variation in the weight. If there is a delay in dividing, corrective steps should be taken, such as by degassing the dough. Where the dough comprises of evenly distributed uniform sized bubbles, the density of the dough remains constant and dividing is more accurate (Rao 2017). Dough is generally divided with portions of a given size, cut either by filling a chamber with dough and cutting off the excess namely piston dividing or by forcing the dough through an orifice at a fixed rate and cutting billets at regular intervals from the end in a process known as extrusion dividing. Moreover, some dividers are coupled with pressure compensators to prevent breakdown of dough bubble structure (Marsh and Cauvain 2007). Mechanical damage can occur when dough faces aggressive tearing between machine parts during this operation and thus, different dividers should be used for different dough types to optimise accuracy and minimal compression damage. For example, typically ‘strong’ North American bread dough can withstand high compression loads, whereas more delicate dough for French baguettes can be easily damaged.

4.6.2 Rounding

When the dough piece exits the divider, it is irregular in shape having sticky cut surfaces through which gas can easily diffuse. The function of the rounder is to shape it into a ball and impart a thick continuous surface skin that will retain the gas and ease the handling or machinability of the dough (Matz 1991).

In traditional hand moulding methods, baker kneads the dough with a rotary motion on the make-up table to produce a ball-shaped piece with smooth skin, except one spot on the base. When two pieces are moulded (one in each hand) using circular motion of one piece against the other, it often helps in imparting the round shape. There are some industrial equipment for high-speed or large-scale rounding in bakeries including:

1. Conical rounder: It consists of a cone which is rotated about a vertical axis with the track of the fixed moulding surface located in a spiral pattern about the outside of it. It is ideal for rounding both soft and medium dough. The cone rolls the dough along the concave spiral-shaped way and enables production of spherical loaves (Marsh and Cauvain 2007).
2. Belt rounder: This equipment can be classified as 'V'-type, vertical and horizontal types. In horizontal type, a track or bar is placed upon or across a conveyor with its axis in the horizontal plane. The belt and straight rounding bar or track set at an angle. The friction generated between rounding bar and the dough causes the dough to get rounded, while it is conveyed on the belt. V type has two belts orientated in a V fashion. One of the belts is driven at a higher speed. The difference in the speed of the belts generates shear and friction. These factors help in shaping the dough and converts the irregular dough into a proper rounded ball (Marsh and Cauvain 2007).
3. Cylindrical rounder: This uses a track around a cylindrical drum to mould the dough pieces (Marsh and Cauvain 2007).

4.6.3 Intermediate Proofing

Dividing and rounding dough causes a drop in its pliability, elasticity and extensibility and thus, the dough may tear easily. It is necessary to let the dough piece rest while fermentation proceeds to restore these properties, so that it recovers from strains and stresses caused by previous operations (Bhatia 2016). This is known as intermediate proofing which is a short rest period of 2–20 min between dough-dividing and the final moulding. During, this process a continued fermentation and a structural relaxation of the gluten take place (Bhatia 2016; Lai and Lin 2006). The length of the intermediate proofing time influences the final bread cell structure, with longer proof times required in products like French baguette that have an open cell structure (Marsh and Cauvain 2007).

Suitable proofing conditions include controlled temperatures (26.7–29.4 °C) and a relative humidity of 75%. Higher temperatures decrease the gas-holding capacity of the dough, producing a sticky mass, while lower temperatures below that range will not allow proper gas expansion due to a slowdown of the fermentation process. Lower relative humidity will harden the dough pieces leading to hard curls and streaks in the bread crumb. If the relative humidity is too high, moisture condensation will occur on the dough surface (Pyler 1988). The changes in dough properties during this period are influenced by other factors such as reducing agents or proteolytic enzymes that have been used to improve dough extensibility (Marsh and Cauvain 2007). There are commercial equipment, such as the pocket-type and conveyor provers for large-scale production bakeries to obtain an optimum intermediate proofing (Marsh and Cauvain 2007).

4.6.4 Moulding

Dough moulding is the terminal step of the dough makeup stage. It is a continuous operation, where the molder receives pieces of dough from the intermediate proving and shapes them according to the bread variety being produced, and makes them ready to be placed in the pans (Bhatia 2016). This process includes 3 basic steps:

1. *Sheeting:* In sheeting, the dough is passed through a series of closely spaced counter-rotating roller heads between which the dough piece is passed to progressively flatten it and reduce the thickness up to one-tenth while the surface area gets enhanced by a factor of more than three. Some systems employ consecutive sheeting rollers of fixed but increasingly narrowing gaps, while other systems use larger drum and roller sheeting where the dough piece is reduced once between a non-stick roller and a drum (Cauvain 2012a; Marsh and Cauvain 2007). Sheeted dough can be easily handled in the later stages of moulding. During sheeting, large gas bubbles within the dough can be subdivided to improve the bubble distribution in the dough and thereby yield a fine structure of breadcrumb.
2. *Curling:* The sheeted dough is carried by a belt conveyor under a flexible woven mesh chain that rolls into a cylindrical form. The rolling operation should produce a relatively tight curl that will prevent air entrapment that can lead to the formation of unwanted holes in the baked loaf. The ellipse that has been created by sheeting is curled through trapping the leading edge underneath a static chain, which creates a roll of dough. The curled dough piece finally passes under a pressure board to eliminate any gas pockets within and to seal the same (Marsh and Cauvain 2007; Rao 2017).
3. *Final moulding:* The final moulder is, basically, a forming conveyor which gives the dough piece its final loaf-type or cylinder shape by exerting downward/outward pressure and forcing the dough against side bars. This operation de-gasses the dough pieces resulting in uniform, tight, and sealed cylinders (Cauvain 2012b). Modern high-speed moulders have several variable speed drives for their different rollers and belts so that they can be fine-tuned for faster or slower production rates.

4.6.5 Final Proofing/Proving

A dough piece which has undergone the processes of sheeting and molding appears degassed and lacks in volume. During this final resting period the fermentation of dough continues in the baking pan for desired dough height. During final proofing, organic acids are formed through yeast activity and contribute to flavour development and increased shelf life. Sufficient time is necessary to enable the dough pieces to relax; otherwise it can result in poor volume and a dense texture. This process is regularly performed at 30–35 °C and 85% relative humidity. The temperature, humidity and time of proofing will depend on the variety of factors such as flour strength, dough formulation with respect to oxidants, dough conditioners, type of shortening, degree of fermentation and type of product desired (Bhatia 2016; Rao 2017).

4.7 Baking

The dough can undergo certain pre-treatments before the final bake, including glazing and scoring. Glazing is a surface coating method for enhancement of the quality factors of bakery products such as increasing the shine or even modify the color of the crust (Jahromi et al. 2012). Glazes which are applied before baking are typically made of whole eggs, skim milk, shortening and may contain various sugars, gums, and starches (Chin et al. 2011; Jahromi et al. 2012). Scoring is the process of making "cuts on their surface" and is one of the characteristics of bread made in different countries as seen in multiple examples in the traditional breads mentioned in this book. By scoring the loaves, the baker creates precise paths for carbon dioxide to escape when the pressure becomes too great inside the dough during oven spring. Consequently, scored dough will expand more during the oven spring and the loaf will increase in volume. The choice of the technique will depend on the type of dough, the type of bread, and the desired final appearance (Suas 2012).

With respect to the baking process, the temperature of this process normally ranges between 220 and 250 °C with variations depending on the oven and product types. The well aerated bread dough coming out of the final proofer has a typical internal temperature close to that of the proof box, around 35 °C. As the dough pieces enter the oven, their surface temperature begins to increase and heat slowly gets transferred towards the core of the product. During baking, the temperature of dough center reaches to about 92–96 °C to ensure that the product structure is fully set (Cauvain 2012b). Baking involves simultaneous heat and mass transfer phenomena (Zheleva and Kambourova 2005). Heat transfer occurs through several mechanisms such as convection through hot air, radiation from heat sources such as flames, conduction through heated surfaces accompanied by condensation of steam and evaporation of water. While heat travels from the surrounding air into the interior of the dough, moisture and other liquid compounds diffuse from the core towards the exterior or surrounding air due to evaporation (Fellows 2009). A series of physicochemical changes occur which are responsible for transforming the raw dough into a baked good with a firm, dry crust and a soft crumb (Jusoh et al. 2013; Rathnayake et al. 2018). As the baking process of the dough starts in the baking oven, it undergoes several physical and biochemical changes which are described below:

1. *Physical changes of the dough during baking*. There is a steady increase in pressure during early baking stages together with other changes in the dough.

   Oven-spring: This change consists in the sudden dough expansion at the initial stages of baking due to an increase in internal pressure of the dough. The following events occur simultaneously to produce the oven spring

- Yeast reaches its maximum fermentation rate and generates CO_2 (CO_2 is also produced by chemical leavening). The yeast activity decreases as the dough warms and the yeast is inactivated at 55 °C.
- Release of CO_2 from the saturated liquid dough phase into the surrounding gas cells.
- Expansion of the gasses trapped in cells (nitrogen from air and CO_2) and generated during mixing, makeup, and proofing.
- Evaporation of water/ethanol mixture.

Crust formation: The dough develops a skin and forms a crust as moisture evaporates from surface of dough during heating. The crust provides the strength of the loaf.

Alcohol evaporation: Low boiling point alcohol formed by the yeast's fermentation evaporates when the temperature is around 80 °C. The alcohol vapours increase the internal pressure which helps in further oven rise.

2. *Biochemical changes during baking*

Starch gelatinization: Starch begins to gelatinize at about 60 °C. The dough now has limited water to completely gelatinize the starch. This limited gelatinization of dough helps in gas retention and setting of bread texture. Gelatinization commences when the temperature is at around 74 °C, and continues until the end of the baking process.

Gluten coagulation: At 74 °C the gluten starts to coagulate, and the chains of protein begin to solidify. This process is called gluten coagulation. Gluten matrix surrounding the individual cells is transformed into a semi-rigid film structure.

Enzyme activity: The action of amylase on starch increases with temperature approximately doubling for every 10 °C rise. Simultaneously, heat inactivation of the enzymes also begins. β-amylases are denatured at lower temperature (57–71 °C) in comparison to α-amylases which denature at higher temperatures ranging from 65 to 95 °C. Inadequate amylase activity can limit loaf volume as the starch can quickly become rigid while excess amylase activity may lead to collapse of loaf.

Browning reaction: The Maillard browning reaction starts at around 150 °C. Under high temperature, reducing sugars react with amino acids of protein or other nitrogen containing substance forming dark colored compounds, known as melanoidins (Wang et al. 2011). This reaction also imparts colour to the crust and flavour to the bread. Pyrazines and pyrroles contribute significantly to bread aroma, notably ethyl pyrazines and 2-acetyl-1-pyrroline (Cho and Peterson 2013; Prost et al. 2012).

Caramelization of sugars: When sucrose is heated to around 170 °C the molecules polymerize to form coloured substances called caramels. This reaction known as caramelization, can only take place in the crust because of the internal loaf temperature never exceeds 100 °C. The caramelized products impart colour and flavour to the baked product (Bhatia 2016; Rao 2017).

4.8 Cooling, Slicing and Packaging

Bread has to be cooled before slicing and wrapping to facilitate slicing and prevent condensation of moisture in the wrapper. Desirable temperature during slicing is 30 °C. Cooling facilitates in redistribution of moisture from centre to the crust softening this layer. The internal temperature of the bread should be reduced to 35–40 °C towards the end of the cooling cycle and this is normally achieved by applying an external air temperature of 24 °C at a relative humidity of 85%, with an air movement. Bread is normally packaged at the legal limit of 38–42% moisture (Bhatia 2016; Rao 2017).

5 Role of Ingredients and Methods for Dough Preparation

A summary of the overall the roles of different ingredients during the development of bread are compiled in Table 1.1.

The complete sequential process of bread making process has been described above including processes common to most types of bread such as dividing the dough, shaping, proving and baking. However, there is significant variation in the methods used to prepare the bulk dough. These may be classified into broad processing groups although there are numerous variations and steps overlapping between each of the individual groups.

5.1 Sponge and Dough Process

In this process a part flour (generally two-third), part of water and yeast are mixed to form a loose batter or dough (sponge). The sponge is allowed to pre-ferment for up to 5 hours. In the next step, the balance of water and flour is added along with other ingredients in the formulation to the fermented sponge, mixed into fully developed dough, which is divided into pieces to produce bread loaves of chosen weights after baking. Sponge and its unique rheological character are carried through to the dough where they have the effect of producing a softer and more extensible gluten network after the second mixing. These dough pieces are then rounded, provided a relaxation period, sheeted and shaped into elongated dough pieces. Thereafter, they are placed into baking pans and transferred for proofing where they are proofed to optimum heights, baked, cooled, sliced, and wrapped (Cauvain 2015a; Cauvain and Young 2007; Kulp and Ponte 2000).

The sponge and dough process produces soft bread with uniform crumb grain structure with unique flavour and aroma. It is commonly used in pan bread, buns and other bread varieties popular in Asian countries, North America and Central Europe. This method is still popular in small bakeries, although it has been

Table 1.1 Role and details of use of commonly used ingredients in bread

Ingredient	Role	Details of use	Reference(s)
Flour	• Protein (gliadin and glutenin) of wheat flour form gluten with water. Gluten retains gas formed by fermentation and contributes to structure of dough and bread. • Starch with water forms a viscous paste on gelatinization that sets to a gel after baking.	High protein (11–13%) patent flour having gluten strength: medium to strong is chosen for bread Bread flour is generally made from the protein-rich endosperm of hard red spring or hard red winter varieties. Some may have a 50–50 blend of hard winter and spring wheat or hard white wheat blended into the mix Several types of bread flour are commercially available, namely, all-purpose flour, enriched flour, gluten flour and self-rising flour. Bread flour is available bleached or unbleached and may contain added malted barley flour and nutrients to improve yeast activity. Flours used in typical sponge and dough production will be at least as strong as those used in bulk fermented dough, with protein contents not less than 12% and high Hagberg Falling Numbers signifying α-amylase activity (typically > 250 s). Larger the proportion of damaged starch in the flour, higher the water absorption of the flour.	Kulp and Ponte (2000), Cauvain (2012a), Dencic et al. (2013), and Stauffer (2007)
Water	• Combines (hydrates) protein to form gluten • Hydrates flour gums (pentosans) and damaged starch granules • Acts as the solvent, dispersing agent, and medium for chemical and biochemical reactions • Aids dough mobility	The amount of water added depends on the type of flour and the dough processing technique. But is usually half the weight of flour used. Too little and the dough will be firm and difficult to mold producing breads that have small volume and poor external appearance. Too much and the dough will be soft and will flow in the prover and give poor-quality bread The water should be slightly warm, 36 °C is ideal, to encourage fermentation by yeast. Too high temperature reduces yeast activity. Water should be clean and potable	Kulp and Ponte (2000), Cauvain and Young (2009), and Cauvain (2012a)

Baker's Yeast *Saccharomyces cerevisiae*	• Produces carbon dioxide, ethanol by fermenting sugars that leavens the dough • Biochemically conditions the dough • Forms flavour precursors which are by-products of alcoholic fermentation	**Type & Moisture content of yeast (%)**	**Shelf Life**	**Method of addition to dough mix**	Kulp and Ponte (2000), Cauvain (2012a), Bhatia (2016), Williams and Pullen (2007), Cauvain and Young 2007), and Bhatia (2016)
		Fresh, compressed Cake Crumbled; 67–72	3–4 weeks	Weigh and add with other ingredients or disperse	
		Fresh, cream (liquid); 80–84	10–14 days	Meter and add with other ingredients.	
		Dry			
		Active dry yeast (ADY); 6–8	1–12 months	Must hydrate at 40–43 °C for 10–15 min, then use.	
		Instant dry; 4–6	1 year plus (depending on packaging)	Blend dry with other dry ingredients or delay addition in mixer.	
		Yeasts are selected based on their ability to fulfil the bakery's requirements, bread type, dough system, processing conditions and equipment. The most favoured pH range for yeast activity is 4.5–6.0. Bread doughs normally have a pH of 5.5 Rate of fermentation depends on level and type of yeast added. Salt and sugar increase osmotic pressure that slows down yeast activity			

(continued)

Table 1.1 (continued)

Salt (sodium chloride)	• Helps control fermentation • Toughens dough by interaction with gluten • Extends required dough development (delayed addition in dough mixing decreases mixing time by 10–20%	Salt can be added with the dry ingredients. Many plant bakeries add the salt through a brine system to ensure accurate metering and to facilitate quick dissolution. Recommended usage is 1.8–2%	Kulp and Ponte (2000) and Cauvain (2012b)
Milk	• Protein (high in lysine) and calcium • Flavour enhancement • Milk sugars aid in developing crust colour through browning reaction and caramelization • Provides buffering effect in doughs and liquid ferments	Milk and dairy products category include whole milk or skimmed milk, skim milk powder, whey and whey mixes that can be added to mix	Kulp and Ponte (2000), Madenci and Bilgiçli (2014), Bilgin et al. (2006), and Graça et al. (2019)
Sugar (table sugar or sucrose)	• Contribute fermentable sugars through enzyme hydrolysis • Imparts sweetness • Sugars take part in Maillard browning and caramelization reactions during baking imparting colour to the crust • Extends shelf life through increased hygroscopicity because of the presence of residual sugars • Tenderizes the crumb	In the UK and many other countries, little or no sugar is used in basic breads Around 6% of flour weight may be present in the sponge and dough breads of USA High fructose corn syrups and dextrose can be used to replace or supplement sucrose in bread formulation	Kulp and Ponte (2000) and Cauvain (2012b)

Shortening	• Eases gas cell expansion in doughs • Lubricates slicing blades during bread slicing • Extends shelf life • Tenderizes crust	Compound bakery fats are often used. The level in which it is used varies with type of flour. Wholemeal flours require higher levels of fat addition than white A proportion of the fat should remain solid in bread dough at the end of final proof, i.e. at 45 °C. In recent years there has been a trend moving from using partially or fully hydrogenated fats towards fractionated or inter-esterified oils	Kulp and Ponte (2000), Cauvain (2012b), Williams and Pullen (2007), and Baker and Mize (1942)
Improvers: This term covers any ingredient added to 'improve' the bread making potential of a given flour			
Oxidising agents	• Promote formation of disulphide bonds through the oxidation of thiol groups of gluten. This strengthens the gluten network, and shortens mixing time • Accelerates the natural aging or maturing of the flour • Bleach flour through oxidation of the carotene and xantho-phyll pigments	The use of oxidizing agents depends on legislation, flour quality and production process. Ascorbic acid is added in a level of 2–6 g/100 kg flour and is as fast acting and tolerant to mixing. Potassium bromate ($KBrO_3$) is a slow-acting oxidant that attains its full development in the oven Recently, some reports have associated bromate with possible health risks. Since then, the use of bromate has been reduced or banned. Potassium iodate is a fast-acting oxidant that improves dough consistency immediately after mixing and development Azodicarbonamide is a maturing agent used in a premix. It is fast acting and provides immediate oxidation when water is added Calcium iodate reacts fast in dough. It is also referred to as lautarite and is prepared by passing chlorine into a hot solution of lime ($CaCO_3$) in which iodine has been dissolved	De Leyn (2014), Gioia et al. (2017), and Panozzo et al. (1994)

(continued)

Table 1.1 (continued)

Reducing agents or reductants	• Weaken the gluten structure in the dough by breaking intra and/or intermolecular covalent disulphide (S-S) bonds between proteins. S-S bonds vanish and sulphydryl or thiol groups (S-H) are built. The advantages are improved machinability, shorter mixing time, reduced proofing time. • This is important when bakeries receive high-protein flours or need to process strong doughs in a short time to reduce energy consumption	L-cysteine is the most common reducing agent added to flour makes dough more extensible and less strong. Usual doses are between 10 and 30 g, 10% l -cysteine/100 kg flour Other reductants in use are sodium bisulphite and sodium metabisulphite	De Leyn (2014) and Gioia et al. (2017)

Emulsifiers	• Some act as dough strengtheners by promoting aggregation and cross-linking of gluten-forming proteins or conditioners while some act as crumb softeners and reduces staling • Improve dough handling properties, increases gas retention capacity for better volume, and extends shelf-life	DATEM (diacetyl tartaric acid esters of monoglycerides) are added to white pan bread, variety bread or buns produced with straight or no-time dough systems. They are added to pre-ferments, like sponges and flour brews, for optimum dispersion. The optimum dosage lies between 0.25 and 0.50%	Gioia et al. (2017), Nunes et al. (2009), De Leyn (2014), and Stauffer and Beech (1990)
		Calcium stearoyl-2-lactylate aids to make crumb structure finer and uniform, extends shelf-life, and improves machinability of the dough. Optimal dosage is 0.25–0.50% on a flour basis	
		Glyceryl monostearate boosts crumb softness. It also retards starch retrogradation. Optimal dosage is 0.2% relative to flour base. It must be emulsified in water before it is added to dough	
		Distilled monoglycerides are used as anti-staling agents as hydrates which are suspensions of monoglyceride crystals (beta -form), usually 20–25% in water having a creamy texture making them dispersible in dough. Blended fine powder of saturated and unsaturated monoglycerides are available which can be added to the dough directly	
		Lecithin produces a finer crumb grain, greater loaf volume, better gluten stability, better fat emulsification, extended shelf-life, and improved water hydration. Pure lecithin is insoluble in water and has to be made soluble. Addition of 0.2% pure lecithin (relative to flour base) gives the maximal improvement possible, depending on the flour quality	
Hydrocolloids	• They augment dough-handling properties, improve the quality of fresh bread • Extend the shelf-life of stored bread • Increase water retention and loaf volume, and decreases firmness and starch retrogradation	Carboxy Methyl Cellulose (CMC) contributes to yielding high volume and retarding staling. Both CMC and guar gum have proven to be beneficial in the formulation of gluten-free breads They must be used in small quantities (<1% flour basis)	Gioia et al. (2017)

(continued)

Table 1.1 (continued)

Wheat gluten	• Increases dough strength (1% gluten increases protein content by 0.6%) • Increases water absorption [1% added gluten (flour basis) enhances absorption by 1.5% (flour basis)] • Improves dough mixing of fermentation tolerance • Increases bread loaf volume	In whole-meal flour or bread having higher quantity of fibers or germs, addition of 5% or more vital gluten leads to good volume and a better texture Vital gluten can absorb almost twice its weight in water (140–180% water) The quality of dry vital gluten is assessed using the Brabender farinograph	Kulp and Ponte (2000) and De Leyn (2014)
Diastatic malt	• Contributes fermentable sugar- maltose • Contains amylases, which convert starches to sugar • Augments flavour. • Improves crust colour • Improves dough handling • Extends shelf life	Diastatic malt is an enzymatic malt produced from sprouted grains, typically barley. Diastatic malt powder contains active amylase that is a constituent of the sprouting process. There are two forms of amylase; alpha and beta. Both of which turn starches into sugars, creating food for the yeast Degrees Lintner is used to measure the diastatic power of malt. The higher the Litner value, the higher the ability of the malt to reduce the starch to sugars	Kulp and Ponte (2000), De Leyn (2014), Doerry (1995), Bera et al. (2018), and Anderson and Sallans (1937)
Enzymes: One of the major reasons behind the revival of enzyme use in the baking industry is the "clean label" trend wherein consumer demands for more natural products with lesser chemical additives. From a regulatory standpoint, enzymes are denatured during baking and, therefore, do not have to be declared on ingredient labels. Those that survive are required to be only labelled as "enzymes." (Yada 2015)			