The Complete Technology Book on Bakery Products
(Baking Science with Formulation & Production)3rd Edition
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Baking is a food cooking method that uses prolonged dry heat by convection, rather than by thermal radiation. Heat is gradually transferred "from the surface of cakes, cookies and breads to their centre. As heat travels through it transforms batters and dough into baked goods with a firm dry crust and a softer centre".

Bakery products have become essential food items of the vast majority of population. The present day consumer looks for new bakery products, better appeal, taste and convenience from bakery foods. Bakery industry has also an important role in popularizing wheat in non-wheat consuming region of the World. With good planning and access to good staff, raw materials and markets, setting up a bakery can represent an excellent enterprise opportunity. The book is invaluable reading for those starting their own baking business or any baker looking to improve their existing business in order to increase profits.

The book covers various aspects related to different bakery products with their manufacturing process and also provides contact details of raw material, plant and machinery suppliers with equipment photographs and their technical specifications. It provides a thorough understanding of the many new developments shaping the industry and offers detailed technical coverage of the manufacturing processes of bakery products. It examines the nature of bakery products, the role of the ingredients in determining their quality, processing methods and their control.

Various bakery products covered in the book are wheat ingredients, other grain ingredients, shortenings, emulsifiers, antioxidants, water and salt, different types of breads and biscuits, cakes, buns, icings, production of cookie and cracker, spices, flavours, colors, leavened and unleavened products, air-leavened products, chemically leavened bread and rolls, chemically leavened sweet goods, Yeast-leavened plain bread, rolls, dough, preservation of bakery products, milk and egg ingredients, fruits, vegetables, nuts and many more.

Food Mixer, Cookie Extruder, Rotary Oven, Biscuit Sandwicthing Machine, Tunnel Gas Oven, Flour Mixer, Cookies Rotary Moulder, Bun Divider Moulder, Planetary Mixer, Spiral Mixer, Pillow Packing Machine, Oil Spray Machine are the various equipments described in the book with their photographs and technical specifications.

The book aims to provide comprehensive information on different types of bakery products. The book is aimed for food technologist, scientists, research scholars, as well as for new entrepreneurs and those who are engaged in this industry.

Content:
1. Ingredients Made From Wheat
   Introduction
   Wheat
   Commercial Wheat Varieties
   Composition of Wheat
   Lipids
   Utilization of Wheat
   Determining the Quality of Wheat

2. Other Grains Ingredients
   Introduction
   Durum
   Special Quality Considerations
   Utilization
   Rye
   Chemical Physical Characteristics
   Triticale
   General Characteristics
   Quality, Composition, and Nutritional Factors
   Utilization
   Rice
   Structure and Composition
   Quality Factors
   Use of Rice in the Baking Industry
   Millet
   Varieties and Distribution
   Structure of the Seed
   Food Uses
   Corn
   Structure and Composition
   Quality Factors
   Traditional Food Products From Corn
   Oats
   Classification
   Structure and Composition
   Barley
   Description of Plant and Seed
   Utilization of Barley
   Structure and Composition of Barley Kernels
   Quality Factors

3. Shortenings, Emulsifiers and Antioxidants
   Introduction
4. Water and Salt

Introduction
Water
Regulations Affecting Potable Water
Water Treatment
Effects of Water Impurities on Bakery Products
Water Treatment Methods Used by Bakeries
Analyses of Water
Salt
Salt in the Human Diet
Containers and Storage
Types of Salt
Salt with Additives
Salt Substitutes in Bakery Products
Analytical Methods

5. Products of Bakery Industries

Bread
Introduction
Market Potential
Raw Materials
Flour
Yeast
Water
Salt
Sugar
Bulk Solids
Flavourings
Enrichment
Bread Manufacture
Straight Dough Method
Sponge Dough Method (Semi-Automatic)
Make Up
Comparison of Straight and Sponge Dough Method
Advantages and Disadvantages of two Methods
Automatic Process to Manufacture Bread
Recipes for Breads
White Pan Bread
Milk Bread
Sweet Bread
Rice Bread
Closed Pan Bread
Sponge Dough
Final Dough
Make up and Baking of the Bread
Egg Bread
French Bread
Straight Dough Method
Raisin Bread
Whole Wheat Bread (Straight Dough Method)
Rye Bread
Rye Bread (Leay Sow)
Vienna Bread
Special Breads
Date-Nut Bread
Low Sodium Bread
Cheese Bread
Specification for Various Types of Breads
White Bread
Other Requirements
Mass of the Bread
Wheat Meal Bread
Other Requirements
Crust and Crumb
(a) Optional Ingredients
(b) Mould Inhibitors
Bread Improver
Requirements
Biscuits
Introduction
Biscuit Raw Materials
Cereals
Sweetener
Shortening
Bonding Materials or Toughers
Tenderizing Materials
Floors
Shortening
Sugar
Lecithin
Milk
Eggs
Rotary Moulded Cookie
Cutting Machine Cookie
Wire Cut Cookie
Spread of the Cookies
Equipments For the Manufacture of Cookies
Wire Cut Machine
Stamping and Rotary Cutting Machines
Rotary Moulded Cookies
Formula for Sugar Wafer Butter
Processing of Sugar Wafer
Coatings for Cookies
Coatings for Cookies Enrobing
Vanilla Coating
Dark Chocolate
Dark Cocoa
Coconut
Peanut Coating
Pie Fillings
Fruit Fillings
Apple Pie Fillings
Banana Cream Starch-Based Gel Filling
Strawberry Flavoured Fillings
Cream Style Fillings
Pie Crusts
The Flour
The Shortening
The Salt
Sugar
Flaky Crusts
Mealy Crusts
Formulations and Procedures for Pie Crusts
Long Flake Pie Crusts
Dough for Fried Peas
Fruit Pie Dough
Mealy Crust Dough
Fried Pies
Faults in Pie Crusts
Soda Crackers
Flour
Water
Shortening
Salt
Yeast Food
Formulas for Soda Crackers
Fermentation
Manufacturing
Absorption
Salt
Sugars
Amylolytic Enzymes
Cakes
The Flour
Soft Straight Flour
Sugar
Shortening
Egg
Milk
Formulation Guidelines
Cake Processing
Common Faults in Cakes
Texture Defects
Defects of Crust Appearance
Too Low Volume
Irregular or Coarse Grain
Various Types of Cakes
Corn Flour Cake
Fruit Cake
Rece Cake
Petha Cake
Maize Floor Cake
Cream Cake
Cheese Cake
Sponge Cake
White Layer Cakes
Rich White Layer Cake
Universal Cake Mix
Yellow Layer Cake
Chocolate Cake
Devil's Food Cake
Chiffon Cake
Layer Cake
Pound Cake
Hard Rolls
Soft Rolls
Vienna (Kaiser) Rolls
Make up of the Rolls
Hamburger Rolls
Make up and Baking of the Rolls
Buns
Bath Buns
Saffron Buns
Cross Buns
German Buns
Sweet Crumb Buns
Round Shaped Filled Bun
Dough
Syrup Wash
Braid Buns
Square Buns
Figure 8 Shaped Buns
Muffins, Nankhatai and Pizza
Muffins
Bran Muffins
Whole Wheat Muffins
Nankhatai
Pizzas
Recipe for Pizza
Icings
Some Guidelines for Icing Preparation
Flavours Development in Icings
Fluffy Icings
Recipes for Various Types of Icing
Chocolate Icing
Butter Icing
Water Icings
Royal Icings
Icing Paste (General)
Vanilla Icing
Butter Scotch Icing
Butter Scotch Paste Icing
Banana Icing
Caramel Boiled Icing
Honey Macaroon Icing
Spice Cake Icing
Orange Icing
Orange Sunshine Icing
Chocolate Fudge Icing
Butter Cream Icing
6. Milk and Eggs Ingredients

Introduction
Ingredients Derived From Milk
Composition of Milk
Types of Milk Ingredients
Milk Protein Concentrate
Dairy Blends and Milk Replacers
Cheese
Quality Tests for Milk and Milk Products
Ingredients From Eggs
Functional Properties
Composition
Commercial Products
Storage

7. Fruits, Vegetables and Nuts

Introduction
Nuts
Almonds, Almond Butter, and Almond Paste
Coconut
Kernel Paste
Peanuts and Peanut Butter
Pecans
Poppy Seeds
Walnuts
Nut Substitutes and Defetted Nuts
Fruits
Dried Fruits
Candied or Glace Fruit
Canned Fruits
Frozen Fruits
Fruit Jams, Jellies and Preserves
Vegetables
Potatoes
Onions
Tomatoes
Carrots

8. Bakery Machinery and Equipment

Weighing Equipment
Manual Scales
Automatic Weighing Equipment
Liquid Measuring Equipment
Mixing
Mixing Equipment
Dry Blenders
Ribbon Blenders
Tumbler with Agglomerate Breakers
Vertical Screw Mixer
Equipment Selection
Continous Pre-Mixing Equipment
Horizontal Dough Mixer
Banbury Mixers
Miscellaneous Horizontal Dough Mixing Equipment
Mixing Mechanism
Vertical Planetary Mixers
Continous Mixers
Temperature and Mixing
Make-up Equipment
Dividers
Effect of Dividing Action on Dough Properties
Divider
Rounders
Controlling and Adjusting the Rounder
Proofer
Tray Type Intermediate Proofer
Maintenance
Intermediate Proofers
Moulders
Moulders for Cookies
Biscuit Rolling Machine
Biscuit Cutters
Fermentation and Proofing Enclosures
Construction Details
Baking Equipments
Ovens
Chamber Type Oven
Draw Plate Oven
Reel Oven
Tunnel Oven
Oven Heating
Fuels
Slicing Equipment
Reciprocating Slicers
Blade Slicer
Packaging Equipment

9. Spices, Flavors and Colors
Introduction
10. **Cookie and Cracker Production**

Ingredients Handling
Mixing
Dough Relaxation and Fermentation
Dough Machining and Forming
Dough Relaxing
Cutting Stage
Scrap Return
Salter of Sugar Sprinkling
Rotary Molding
Extruder-Dough Formers
Wire Cut
Rout Press
The Fruit Bar Co-Extruder
Baking
Direct-Fired Ovens, Gas Fired
Convection (Indirect) Ovens
Post Conditioning
Secondary Process
Icings
Enrobing
Sandwiched Cookies and Crackers
Biscuit Packaging

11. **Unleavened Bakery Products**

Introduction
Pie Crusts
General Considerations
Types of Pie Crusts
Baked Pies
Long-Flake Crust
Short-Flake Crust
Mealy Crust
Pressed Crumb Crusts
Savory Pies
Fried Pies
Causes of Faults in Pie Crusts
Strudel, Phyllo and Egg Rolls
Unleavened Cookies

12. Products Leavened Primarily With Water Vapor
Puff Pastry
Theoretical Considerations Affecting Layering
Practical Methods of Puff Pastry Production
Traditional Puff Pastry method
Automated Puff Pastry Production
Formin and Baking Puff Pastry
Trouble Shooting Puff Pastry
Crispbread
Eclair Shells, Cream Puffs, and Popovers
Cookies and Crackers
Beaten Biscuits
Puff Biscuits
Sugar Wafers

13. Air-Leavened Products
Introduction
Angel Food Cakes
General Considerations
Ingredients and Formulas
Procedures
Meringue Layer for Tortes
Foam Type Angel Food Cake
Continuous Mix Angel Food Cake
Cakes Made With Foams of Whole Eggs or Egg Yolks
Effects of Whole Eggs
Pound Cakes
Sponge Cakes
Chiffon Cakes
Cheese Cakes
Snow White California Cheese Cake
Fruit Cakes
Cookies

14. Chemically Leavened Bread and Rolls
Introduction
Chemical Leavening Systems
Effects of Air, Water Vapor, and Carbon Dioxide on Volume
Characteristics of Chemical Leavening Systems
Function of Ingredients
Soda Breads
Buttermilk Bread
Irish Soda Bread
Irish Soda Bread
Boston Brown Bread
Chemically Leavened White Bread
Other Bread Varieties
Soda Biscuits
Scones
Muffins
Veggie Muffins
Snack Crackers

15. Chemically Leavened Sweet Goods
Composition
General Rules For Developing Formulas
Layer Cakes
Examples of Cake Formulas
Processing Chemically Leavened Sweet Goods
Trouble Shooting Cake Faults
Cup-Cakes
Cake Doughnuts
Formulation and Processing
Doughnut Trouble Shooting
Cookies
Relationship of Formula to Processing Method
Ingredients
Representative Formulas

16. Yeast-Leavened Plain Bread and Rolls
Principles of Plain Bread and Roll Production
White Bread
French Bread
White Rolls
Wheat Bread
Two Traditional Bread Processing Schemes
Straight Dough Method
Sponge-and-Dough Method
Reaction During Mixing
Dough Development
Establishing Vesicle Size
Conditioning the Dough
Temperature Rise During Mixing
Fermentation
Bulk Fermentations
Proofing
Pan Proofing
Dividing and Rounding
Bread-Molding Processes
Roll-Forming Processes
Baking
Effect of Form and Size of the Dough Piece
Cooling and Depanning
Defects of the Crust
Defects in the Crumb
Defects of Volume
Defects of Taste or Odor
Defects in Shelf-Life

17. Doughs
Introduction
Continuous Processing of White Bread and Rolls
Principles of Operation
Formulating White Bread for Continuous Plants
Making Fermentation Processes More Efficient
Three Kinds of Sponge Replacement Systems
Conditioning by Mechanical or Chemical Means
Systems Relying Principally on Chemical Modification

18. Breads
Sour Dough Breads
Microflora of Sour Doughs
San Francisco (Pacific Slope) Sour Dough Bread
Sour Dough French Bread
Panettone
Salt-Rising Bread
Rye and Multi-Grain Breads
Multi-Grain Breads
Rye Bread
Rye Bread Formula and Process
Other Variety Breads
Breads with Vegetable Ingredients
Breads with Dairy Ingredients
Dietetic Bakery Products
Reduced Salt
Reduced Fat
Gluten-Free
"Diabetic" or Sugar-Free
19. Yeast-Leavened Sweet Doughs
Plain and Roll-In Sweet Doughs
Ingredients
Formulas, General
Straight Sweet Dough Formula and Procedure
Sponge Sweet Dough Formula and Procedure
Roll-in Sweet Dough Formula and Procedure
Procedures
Fruited Rolls and Stollen
Doughnuts and Other Fried Goods
General Formulas
Ingredient Specifications and Functions
Procedures
Danish Pastry
History
Experimental Studies
Ingredients and Formulas
Procedures
Examples of Products
Almond Crumb Coffee Cake
Apple Filled Coffee Cakes
Yeast-Leavened Cookies
Fried Yeast-Leavened Cookie

20. Preservation of Bakery Products
Introduction
Refrigerated Dough Products
Freezing Preservation
Freezing Equipment and Methods
Freezing Doughs and Batters
Freezing Baked Products and Adjuncts
Heat Processing in Hermetically Sealed Containers
Modified Atmosphere Packaging
Chemical Preservation
Irradiation
Other Methods

21. Photographs of Machinery and Equipment
Food Mixer
Cookie Extruder
Rotary Oven
Pillow Packing Machine
180° Layout Turning Machine
Oil Spray Machine
Biscuit Sandwiching Machine
Tunnel Gas Oven
Rotary Print Biscuit Forming Machine (Soft Biscuit)
Tunnel Electric Oven
Flour Mixer
Cookies Rotary Moulder
Bun Divider Moulder
Bread Moulder
Double Trolley Bakery Oven
Cookie Dropping Machine
Planetary Mixer
Spiral Mixer

22. Raw Material Suppliers
Starch
Bakery Chemicals
Baking Enzymes
Baking Powder
Bread Improver
Cake Gel
Egg Powder
Flavouring Emulsion
Flexible Packaging
Glucose
Lecithin
Plastic Crates
Milk Products
Wheat Gluten
Yeast

23. Machinery and Equipment Suppliers

Sample Chapter:
COOKIE AND CRACKER PRODUCTION

INGREDIENTS HANDLING

Most ingredients fall within one of three categories: bulk dry (i.e., flour and sugar), bulk liquid (i.e., fats and oils), and minor ingredients (i.e., leavening agents). Each category requires specific storage conditions, such as time and temperature, to minimize undesirable changes during storage. Samples of raw materials are routinely tested in the quality control (QC) laboratory for compliance with the specifications. We can define bulk ingredients as those that are not packed in containers of a given size, such as 100-lb bags, 30-gal drums, or 50-lb cartons. Bulk handling has contributed greatly to improved efficiency, labor savings and hygiene in cookie and cracker plants.

Many of the ingredients should be pre-processed prior to blending and mixing. This is especially true for minor ingredients of small but critical amounts, which should therefore be blended with another ingredient (i.e., flour) as a "carrier." Sometimes sugars are also milled to a certain particle size prior to mixing. Major ingredients will then be transferred via pneumatic or screw conveyers to use bins, which usually hold enough material for 3-8 hours of production. Flour and sugar, as well as other ingredients, pass through sifters and filters to remove extraneous material prior to going to use bins.

Weighing and metering are done by scales and pumps located on the tops of the mixers. Metering is probably the most important area of process control, as errors here have an effect throughout the rest of the factory. For that reason, numerous metering systems with programmable logic controllers (PLCs) and electronic weighing have been developed in the last two decades. Occasionally minor ingredients in already weighed bags will be poured into the mixer by the operator prior to starting the mixer.

MIXING

The quality of dough is determined by the recipe, the quality of the ingredients used, and the degree to which these ingredients are mixed together. Probably the greatest variations in dough consistency arise from imperfect metering of ingredients.

There are at least three types of mixers used in cookie and cracker plants. Vertical spindle mixers are very popular for mixing cracker doughs, because the trough is removable and is best suited for two-stage mixing (19 hours apart) of saltine cracker doughs, where it remains in the trough for sponge fermentation, dough-up, and dough fermentation (a total of 24 hours). The spindles (two or three per mixer) rotate at several speeds up to 20 rpm; therefore, the mixing action is gentle and the amount of gluten development is minimal. Because of this slow speed and lack of temperature-controlling jackets, the use of spindle mixers is specifically limited to fermented crackers.

High-speed mixers (also called horizontal drum mixers) are by far the most widely used mixer type in modern biscuit bakeries. A wide range of mixers of different sizes and capacities is available. They consist of a U-shaped horizontal trough to hold from 1000 to 3000 pounds of dough. Unlike the spindle mixers, the mixing takes place in a closed space. The mixing arms rotate at speeds ranging from 30 to 100 rpm. The design of the rotor and paddles varies considerably in different makes of mixers. Most high-speed mixers have water jackets (usually cold), but since the surface of the mixer is small relative to the mass of the dough, and the time the dough is in the mixer is quite short, these jackets are usually limited to helping prevent the temperature from rising too much, rather than having any positive cooling effect. It is therefore more effective to correctly control the ingredient temperature.
Continuous mixers have single or twin screws enclosed in a jacketed cylindrical casing. The ingredients are fed through various hoppers at one end of the cylinder, and the dough is extruded continuously at the other. The mixing time is quite short (30-60 s). Without doubt, continuous mixers are best suited for making doughs and batters, especially as their output can be precisely matched to the rest of the production plant so that all dough is of uniform age. Starting and stopping the continuous mixer is not easy, however, and requires some period of adjustment after each start-up. Therefore, it is mainly used in large, dedicated production lines.

DOUGH RELAXATION AND FERMENTATION

After mixing, doughs are left to relax or ferment for a wide range of time, from 30-45 minutes for cookie doughs, to 2-3 hours for chemically leavened cracker doughs, to up to 23 hours for yeast-fermented cracker doughs. At this stage the dough is either in the original mixing tub for the spindle mixers, transfer tubs for the high-speed mixers, or continuous proofers (or transfer tubs) for continuous mixers.

DOUGH MACHINING AND FORMING

At the completion of the relaxation or fermentation periods, doughs are dumped onto the hopper for machining, which is called the machining and forming stage, and differs according to the finished-product properties. There are three basic ways to machine cookie and cracker doughs:

- Sheeting and laminating for crackers and some cookies
- Rotary molding
- Extrusion, that is, wire cutters, bar presses, and fruit bar co-extruders.

For the doughs that go through the sheeting and lamination operation, the first step is called pre-sheeting. In this part of the process, a set of heavily serrated, contra-rotating steel rolls, about 40 inches in diameter, that are installed immediately under the dough hopper, pull the dough from the hopper. The rollers produce a rough, thick, and serrated dough sheet that drops vertically onto a flat horizontal cotton conveyer. It is necessary that there are no significant holes and that the edges are smooth and not ragged. Often, the sheeter also enables the incorporation of dough returned from the cutter, known as cutter scrap, with fresh dough brought from the mixer. The cotton conveyer transfers the dough to the next stage, which could be laminating. Some of the doughs do not require the laminating stage, in which case, the doughs are transferred to gauge rolls.

The pre-sheeter roll acts as a meter to feed the dough to the baking line at the required rate. Their speed and gap is therefore adjustable. Pre-sheeters come with either two, three, or rarely, four rolls. There are also front and back-discharge three-roll pre-sheeters. The back-discharge variety is preferred for all extensible doughs, while front discharge is required when the dough is weak and short and needs to be well supported as the sheet leaves the pre-sheeter. It should be noted that the greater the height of the dough in a hopper, the more pressure at the pre-sheeter, and therefore the more extrusion of dough through the machine. Thus, the delivery rate of a pre-sheeter is affected by the level of dough in the hopper.

Many types of crackers and sweet goods have to be made from a layer of dough that itself is made of several thin layers. In the oven, this configuration will help the dough give the desirable layered structure to the finished product. This process is called lamination.

Prior to the advent of the modern automatic laminator, biscuit doughs and pastries were laminated by hand. The purpose of laminating can be stated by the following four points:

- It is a method of repairing a poor dough sheet that may be formed with pre-sheeter rolls.
- By turning the folded dough through 90°, stresses in the dough are made more uniform in two directions.
- By rolling, then folding the dough, followed by more rolling, a significant amount of work is done on the
gluten, making it more suitable for baking a desirable structure.

By introducing another material, like fat, between layers of dough, a characteristic flaky structure can be produced.

The lamination process has two very different styles: folding and cut-and-lay. There are basically three types of laminators available on the market today: horizontal, vertical, and stacked horizontal. Horizontal laminators are becoming extinct, however, because they are inconvenient to use and because of the amount of floor space they occupy.

The more commonly used vertical laminator takes up much less space since it is installed immediately under the pre-sheeter serrated rolls. It consists of two or three sets of smooth-gauge rolls. The dough is fed through the hopper vertically to the pre-sheeter and gauge rolls, and is folded down onto a transfer conveyor by a reciprocating movement, which transfers the laminated dough to the sheeting stage. This system is well suited for tough, highly developed doughs.

The stacked horizontal laminator is a cross between a horizontal and a vertical laminator. In essence, it consists of a horizontal laminator in which the various sections are stacked one above the other instead of being sequential on the floor. The presheeter is fed from the floor above and forms the initial sheet of dough on a short horizontal conveyor. The dough then comes back under itself through the first pair of gauge rolls, then forward under itself again through the second pair of gauge rolls, before being cross-laminated on the infeed conveyor of the second sheeter system.

All three types of laminator can deliver the sheeted doughs to the second sheeter system either folded or by cut-and-lay. For the folded lamination, the thin sheet of dough is laid backward and forward across a conveyor that feeds to the second sheeting system. While this conveyor is continuously moving forward, the sheets are laid in a zig zag pattern, showing alternate “triangles” of the upper and lower surfaces of the original sheet.

For the cut-and-lay lamination, the dough sheet from the last laminating gauge roll is cut into “square” pieces, the length of which match the width of the last gauge roll. These pieces are laid one on top of another. While the conveyor moves forward, successive sheets are laid a few inches behind the previous one. After being sheeted by the serrated pre-sheeter rolls, the dough, whether or not it is to undergo lamination, should proceed through a series of gauge rolls to form a sheet of the required thickness. Gauge rolls are two large smooth steel rolls, one above the other, approximately 15 inches in diameter, and as long as the width of the baking line. The gap between the rolls can be set very accurately. In practice, the reduction in thickness should be about 2:1 or 50%, although, ratios of up to 4:1 are used. Obviously, the greater the ratio, the more work and stress is put into the dough. For most products there are two or three sets of gauge rolls after the sheeter. A scraper knife is normally used on the bottom roll to release the dough sheet. The final control of the dough sheet thickness and consequently the final product weight is the responsibility of the final pair of gauge rolls. All gauge rolls should have instruments indicating the gap setting so that the machine can be changed or the settings recorded with accuracy.

Dough emerging from a gauge roll is always of a slightly greater thickness than the gap it has come through due to the elastic properties of the dough, as well as to some extrusion occurring through the roll gap.

**DOUGH RELAXING**

The repeated "working" of the dough in one direction through the various sheeter and gauge rolls tends to introduce stresses within the dough, particularly with hot or developed doughs. If the dough is cut before these stresses are relieved, the cut piece will tend to relax in the oven, and misshapen biscuits will result. It is usual, therefore, to "relax" the dough sheet after gauging, but before cutting. The dough is relaxed by giving it time, as well as by allowing it unlimited shrinkage. A significant length of the conveyor - anywhere up to 15-20 feet, depending on the size and speed of the line - may be needed between the last gauge rolls.
and the cutting machine. This conveyor is run more slowly than the takeaway conveyor from the last set of
gauge rolls, so that the dough sheet, which is grossly overfed onto this conveyor, "ripples" crosswise as it
transfers. During its passage to the cutting machine, these ripples fade away as the dough sheet shrinks
longitudinally, thus relieving the stresses built up in it. The sheet must of course have become flat before it
reaches the cutting machine, and the conveyor speed and the consequent size of the ripples have to be
adjusted to achieve this cutting stage. In many of the cracker production lines the dough relaxing stage is
located after the cutting stage, and is the last stage of machining prior to baking. This relaxation process is
very delicate and needs constant supervision. On many occasions, the ripples are not completely removed
before cutting; in other cases, the dough is pulled off the intermediate conveyor onto the cutting web,
thereby again introducing some stress. The deep rippling also allows circulation of air under the dough,
which can be a disadvantage, because preferential adhesion to the cutting web rather than the cutter is
required.

**CUTTING STAGE**

After the dough ripples have smoothed out, the sheeted dough is ready for cutting to any desired shape.
There are basically two types of cutters available on the market today: reciprocating and rotary.
The reciprocating cutter has been used in the cookie and cracker industry for a long time and consists of a
sharp-edged metal cutting "shape" that is brought down vertically onto the dough sheet with sufficient force
to cut through the sheet. As the cutter rises after cutting, it leaves behind the cut biscuit "blank" surrounded
by the unused scrap dough. The blank is transferred via a "panning web" to the oven band and the
surrounding scrap is picked up by a scrap conveyor and transferred back to the feed end of the sheeter unit
for reuse.

The equipment needs to be strong, and it incorporates a swinging mechanism. This mechanism is
necessary because after the cutter drops, it moves with the dough, then rises and swings back before
dropping again. Reciprocating cutters thus require a heavy mechanism with many moving parts that need
good lubrication and maintenance. They are often noisy, especially if the plant is run at high speed.
The rotary cutter is a simpler system and requires less space than the reciprocating cutter. It has very few
moving parts, is much lighter in construction, and is usually more easily adjusted to the speed of the
production line. Rotary cutters are of two types, those that employ two rolls, one immediately after the
other, and those with only one roll. Both types are equipped with an additional rubber-coated roll, which is
installed under the web. For the two-roll type, the first roll dockers the dough, prints any surface pattern or
type, and pins the dough onto the cutting web. The second roll is engraved with only the outline of the
biscuit and cuts out the piece, leaving a network of scrap dough. A single-roll rotary cutter achieves
dockering, pinning, and outline cutting with only one roll. In practice, the two-roll rotary cutter is superior to
the one roll.

The cutter is sometimes coated with plastic or Teflon to keep the dough from sticking to it.
The performance of the cutters, whether rotary or reciprocating, is significantly affected by the surface of
the cutting web that carries the dough. The webs are usually woven cotton canvas or are a cotton/
polyester mixture, but sometimes plastic-coated webs are used.

Rotary cutters have gained popularity in the past few years, and today most new installations incorporate
rotary rather than reciprocating cutters.

**SCRAP RETURN**

With most sheeted crackers and cookies, there is a large amount of scrap dough (up to 60%), all of which
has to be returned as soon as possible to the feed end of the line for reincorporation with the new or "fresh"
doughs. Scrap dough is normally handled in one of three ways: overhead scrap return, side scrap return, or
return into the mixer. Overhead scrap return consists of a woven cotton or suitable plastic-faced conveyor,
the same width as that on the sheeting machine, mounted directly above it, and running back toward the dough feed hopper at the start of the baking line. The advantage of this type of scrap return is that the scrap, which has already been "worked" in the sheeting machine, is distributed evenly across the width of the feed hopper, so its effect on the new dough is uniform. In the most recent designs, the scrap dough is sheeted by a set of gauge rolls, and then the thin scrap sheet is laid under the dough sheet made from fresh dough.

The side scrap return is the more common method. The "lift-off" conveyor deposits the scrap dough onto a similar narrow conveyor running back off the side of the sheeting line. Once the scrap reaches the dough feed hopper, it is delivered onto a reciprocating chute that swings backward and forward over the width of the hopper, distributing the scrap dough more or less evenly throughout. This chute is normally placed behind the delivery chute of new dough from the pre-sheeter, so the scrap dough is mostly placed on the dough sheet from the pre-sheeter. Any variation in the appearance of the dough surface due to the incorporation of scrap is thus on the bottom of the eventual biscuits. The advantages of side scrap return, and the fact that it can be used for most doughs, normally makes it preferable.

The return of scrap into the mixer is less common because of the difficulty in synchronizing the mixing intervals with scrap dough return. Whichever method used, however, it is important to ensure that the scrap dough is spread evenly in the sheeter to optimize a good distribution in the new dough.

SALTER OR SUGAR SPRINKLING
If required by the formula, salt, sugar, or nuts and spices will be sprinkled on top of the dough pieces after the cutting stage is completed. The excess sugar or salt on the band will be removed by spaces between the two conveyor segments or by the incorporation of a small wire mesh conveyor under the sprinkler. At this stage, a milk, honey, or egg wash may also be applied. This is done either by spraying or by a revolving brush.

The finished dough pieces may be transferred directly onto the oven band from the cutting web or via another web known as the panning web. The panner unit allows for careful adjustment of the spaces between the dough pieces that are going into the oven.

ROTARY MOLDING
Rotary molding is a simple, efficient, and convenient way of machining short doughs. The problems of sheeting, laminating, and gauging are eliminated, and there is no scrap dough for recycling, which means more uniformly developed dough pieces. Because the mold can have different shapes, one can have more intricate pattern outlines than with cut dough, and the pieces can have hollow centers if required, but molds are only suitable for cookie doughs of a relatively dry, crumbly nature. The system consists of three rollers installed under the dough hopper in a triangular shape. The upper two rolls consist of a heavily serrated roll that pulls the dough down from the small hopper and forces it into biscuit-sized impressions in the engraved roller. At the narrowest point between the two rollers, a knife scrapes any excess dough from the surface of the engraved roll, leaving the biscuit impressions in the roll full of dough. Beneath the engraved roll is the third "extract" roller that is covered with thick rubber to make it resilient. This roller drives the cotton takeaway conveyor wrapped around it. Pressure is applied on the engraved roller by the extract roller, causing the dough in the engravings to adhere preferentially to the cotton conveyor, which carries the dough pieces away to the baking line. The surface of the cotton conveyor must be sufficiently rough or sticky to allow good adherence by the dough piece. If the mold is very deep with docker pins, it may be difficult to remove the dough piece. If the dough is extensible, it may be released from the mold between the knife and the extraction point, which reduces molding efficiency and causes dough scrap. Therefore, extensible doughs should not be rotary molded. The level of dough in the hopper is usually maintained at a minimum to avoid pressure differences
at the nip and excessive working and toughening of the dough. The engraved roller is usually made from heavy brass with biscuit shapes engraved into the surface. In recent years, however, some manufacturers, have offered molded plastic inserts that are put into simple circular or rectangular holes in the roller.

**EXTRUDER-DOUGH FORMERS**

The three types of extruder-dough formers are used when the dough is short and usually soft, and even pourable. Products made from extruded and deposited doughs tend to be from richer formulas and to be more irregularly shaped than most.

**WIRE CUT**

The doughs that are to be wire cut may be viscous and relatively firmer than other extruded doughs. Wire cutting makes it possible to form pieces from stickier doughs and doughs containing such coarse particles as chocolate drops or nuts.

All machines basically consist of a hopper over a system of two or three rolls that force the dough into a pressure chamber above the oven band. Dough is extruded through a row of dies (of any desired size or shape) and a frame bearing a wire or knife strikes across the base of the die holes, "cutting" off the extruded dough at intervals.

Wire-cut machines are not fast, rarely exceeding 100 strokes per minute. The number of deposits could be increased, however, by installing double-roll dies or another wire-cut machine.

**ROUT PRESS**

A thinner dough or batter is normally used in rout press operations, as it is extruded continuously as a ribbon. The die is therefore shaped to suit the cross section of the dough piece, and the die plate is usually inclined in the direction of the extrusion so that the ribbons can be transferred onto the conveyor as smoothly as possible. The dough can either be cut vertically into pieces by a swing-head guillotine in front of the oven, or after baking, according to the product required. Depending on the character of the dough in terms of coarse ingredients and consistency, the bar cookies may have smooth or rough edges and surface.

**THE FRUIT BAR CO-EXTRUDER**

In the fruit bar co-extruder, two different doughs (casing and filler) or one dough and a fruit paste are coextruded one within the other. This arrangement is used in the production of fig bars. The filled tube thus produced may be cut before or after baking as described earlier.

If the dough consistency is soft, smooth, and pourable, it is possible to produce deposited rather than wire-cut types if the die plate is replaced by a set of piping nozzles. By using variable depositing times and mechanisms, such as twisting of the nozzle, it is possible to produce a variety of products, such as fingers, swirls, circles and other shapes. Also, if a second depositor is synchronized with the first, it is possible to deposit jam (or jelly) or another dough on or within the deposit made by the first.

**BAKING**

Nearly all commercially made biscuits are now baked in band or traveling ovens. A traveling or band oven consists essentially of an insulated tunnel, usually anywhere from 100 to 300 feet in length, through which passes a steel conveyor band, usually from 25 to 100 inches wide, on which the dough pieces are carried. The tunnel is heated internally either directly (e.g., by gas or electric heaters within the baking chamber-direct gas fire), or indirectly by hot air (or products of combustion) circulated through the oven from an external heat source (convection), or by a combination of the two systems (hybrid).

The conveyor band can be of solid sheet steel or various types of woven wire mesh, depending on the type of biscuit being made.

For a typical product, baking takes place in three successive stages. In the first, structural changes take
place in the dough; the thickness of the piece slowly increases (often several fold) due to aeration of the
dough. This thickness gradually "sets" until the dough piece has taken on the approximate size and
thickness of the final product. The second stage is where the greatest loss of moisture content of the piece
takes place. In the third stage the coloring of the biscuit occurs, changing the pale dough product into the
typical light brown color of the finished biscuit—though color can vary from the near white of some types of
 crackers, to the dark brown of some sweet biscuits.

**DIRECT-FIRED OVENS, GAS FIRED**
The direct-fired oven, gas fired (DGF), is the simplest and most commonly used oven in the biscuit industry.
It features a series of individual burners that are located within the baking chamber, both above and below
the baking conveyor. In this type of oven, the heat is transferred directly to the biscuit by radiation-energy
waves from the heat source to the product. Part of the heat generated by the burners beneath the conveyor
heats the band, and is then transferred to the bottom of the product by means of conductance.

**CONVECTION (INDIRECT) OVENS**
Convection ovens are ovens in which the products of combustion are circulated within the baking chamber,
but the gas burners are outside it. These ovens usually have a single burner for each section. There is
therefore no direct radiant heat transfer to the product from the burner (and little from the oven walls), and
baking is achieved largely by convection.

There is a convection oven called a forced conviction oven. In a forced convection oven the products of
combustion are kept separate from the oven atmosphere. An oven of this type is basically similar to the
convection oven, but has a gas-to-gas heat exchanger behind the burner. The products of combustion are
vented to the atmosphere immediately behind the exchanger. The baking chamber air is recirculated
continually with only minor "bleed off" to atmosphere to compensate for the increasing humidity from the
drying out of the biscuits.

If the chamber is heated through slotted tubes, or orifices laid out in patterns extending across the width of
the band, the oven is then called an impingement oven.

For some applications, users have found it advantageous to install a combination or hybrid oven. These are
ovens in which one form of heating is used at one end and another form at the other, for example, the direct
gas fire section at the beginning of an indirect oven. The users of convection ovens sometimes use a
couple of zones of direct gas fire that are equipped with burners or electric radiant panels to provide a
higher temperature for better "lift" to the dough at the initial stage of the baking. The use of hybrid ovens is
somewhat limited in the biscuit industry.

All the various types of ovens are equipped with bands that are either flexible solid steel sheet or woven
steel wire. The smooth solid steel band with a thickness of about 2 mm is used for rotary or extruded (wire-
cut, route-press) cookies and shortbreads. Since the dough cannot grip the band, it will flow in the oven,
making control of product size and dimension somewhat difficult. These steel bands also produce a thinner
bottom crust than the wire meshes do, and thus contribute to a softer bite in the finished product being
solid, the band holds the heat well, so it is good for products that need an initial surge of heat. Sometimes
Solid bands are perforated, making it a cross between a solid and a wire mesh band in properties. This
hybridization allows the release of steam and leavening gases from the base of the dough pieces, thus
avoiding uneven or "hollow" backs on the product.

The wire mesh bands, due to significant spaces between the pieces of wire, allow the heat free access to
the dough from beneath and free exhaust of steam from the underside. These bands are more suitable for
stiff cracker doughs. The dough also has a better grip to the wire mesh band.

All modern ovens, whether direct-fired or indirect, are divided into a number of zones, normally of equal
length, but this could be varied. Some have more and shorter zones at the beginning of the oven where
control tends to be more critical, with longer zones near the delivery end where "drying out" and coloring are relatively slow, straightforward processes. This is the "profile" of the temperature of the oven from one end to the other. Every product will have its own profile—some a high temperature is required at the beginning (e.g., crackers), for others in the center (e.g., semi-sweet), and for some a fairly uniform profile throughout (e.g., short-bread).

Many of the products leaving a conventional oven have a moisture content in excess of the product specifications required for expected shelf life as well as textural characteristics. This is mainly caused by speeding up the oven conveyor to increase the throughput, thus not allowing adequate time for optimum moisture removal. Occasionally, excessive moisture removal by conventional ovens may cause too much browning as well. A second oven is therefore needed to reduce the moisture. This is usually accomplished by installing either a micro-wave or dielectric heating system at the back end of the conventional ovens. This arrangement may allow a significant increase in the oven throughput. The product structure is set in the oven and browning reaction occurs, but the required moisture loss occurs only partially in the oven and is completed in the microwave or dielectric oven.

The product leaving a conventional oven at too high a moisture content is rapidly transferred to a conveyor made of insulating material and is then passed through a carefully designed horizontal alternating electric field. At the frequencies used, the power is selectively absorbed by water molecules, which consequently evaporate and diffuse out of the product.

Another useful "post-conditioner" can be an infra-red radiant section that uses special lamps or radiators. An oven chamber is designed for general baking purposes and is often unnecessarily cumbersome for simple "browning" of the biscuit surface. Where some extension of oven capacity is required, therefore, it can sometimes be achieved by the use of infra-red radiators above the extended oven run out.

POST CONDITIONING

Biscuits coming out of the oven are too hot to be packaged, so they are transferred to a cooling band, which is mostly an open conveyor running between the end of the oven and the wrapping machines. Cooling is also necessary for sugar-rich biscuits, as these are very soft as they leave the oven and only set rigid when cool. There is also an appreciable loss of moisture as the biscuits cool, and this is beneficial to their quality and shelf life.

The normal method of cooling biscuits is to place them flat on an open conveyor, usually slightly wider than the oven band, and carry them for a distance usually equivalent to 1.5-2 times the oven length, allowing the biscuits to cool naturally in the ambient factory atmosphere.

There are several occasions when natural cooling of biscuits may be inadequate, making some form of forced cooling required. Where there is either inadequate time or space for ambient cooling, a forced cooling tunnel may be necessary. One negative aspect of forced cooling is the potential increase of "checking" in some products. Checking occurs as a result of microscopic cracks, usually across a central portion of the biscuit, making it susceptible to complete breakage on subsequent handling. Checking can be reduced if baking is slow and cooling gradual. The use of a post oven dielectric drier could effectively reduce checking irrespective of subsequent cooling arrangements.

After cooling, the biscuits could go through various processes prior to being packaged. For those that are dump-packed, the product is transferred to several conveyors that are narrower than the cooling conveyor, and moves to the packing department. The product is weighed according to the package specifications and dump-packed either in bags or boxes. The packing may require stacking the biscuit from the cooling conveyor prior to the packing machines.

SECONDARY PROCESSES
In some cases, biscuits are subjected to further processing after cooling, such as coating or sandwiching with flavored material such as chocolate, fat-based creams, icings, marshmallow, peanut butter or jam or jelly. Through secondary processes, a much greater variety of flavors, textures, and appearance can be achieved than by baking alone.

**ICINGS**

Icing may be defined as a glazing or coating of sugar and other ingredients used for improving the taste and appearance of cookies. It is simply a mixture of very fine icing sugar in water with some flavorings and a gelling material, such as gelatine or pectin, to give it some “body” and increased viscosity. Icing is applied on the biscuit as a thick aqueous suspension. After cooling and drying, it will have a hard finish. There are many types of icings used in the cookie industry, and the method of application depends on the composition of the icing and the expected finished appearance. It is, however, basically an in-line process. The icing ingredients are mixed and then pumped through a transfer pipe to the nozzles or depositors. One technical difficulty is the hygroscopic nature of cookies and the potential moisture uptake from the water-based icings by the base cake. This can be avoided by quick drying the icing to avoid softening of the cookie base cake. The drying process has a profound effect on icing sugar crystallization that affects the texture. The finer the crystal size, the creamier the texture.

Sugar wafers are actually icing sandwiches. An icing mixture is spread onto a wafer sheet and a top sheet is added immediately. The sandwich is then dried and subsequently cut with saws or wires into fingers or rectangles before packing.

It is essential that drying proceed without delay so that moisture penetration is minimal and dimensional changes do not cause cracking of the icing at the latter stages in drying. The maximum temperatures in the drier should be 80Â°C (175Â°F), because above this, bubbling and cavity formation will be severe, giving a poor structure to the icing and causing weak adherence of the icing to the biscuit.

**ENROBING**

Many types of cookies are enrobed with chocolate and other compound coatings. The advantages of enrobing are improved appearance and enhanced flavor. Enrobed compounds also act as moisture barriers and prevent the cookies from drying out while maintaining crispness. Occasionally, they may also provide structural strength for the cookies and therefore reduce breakage. The compound coatings are formulated with stable fats, and maintain their flavor, mouth feel, and richness for many months. To enrobe a cookie, the baked item should be at a room temperature of 75° to 85°F (24°-29°C). The coatings are usually tempered by a controlled cooling and heating process to improve its stability.

Enrobers have an open wire mesh conveyor up to 5 ft wide that carries the biscuits through a bath of chocolate circulated from below and through a curtain of chocolate poured from above. In the case of only half coating, the curtain is not used.

Having got the chocolate onto the product, the excess must be removed so that only the desired pick up is achieved. Excess chocolate on the tops of biscuits is blown off with an air. Current directed downward and of even velocity across the width of the enrober. The air must be warm, and is thus recirculated within the enrober under the hood.

A vibrating or shaker device encourages excess chocolate to run off the coated biscuits while evening out any ripples on the surface that were produced by the air curtain. The biscuit is then transferred to another conveyor for cooling.

**SANDWICHED COOKIES AND CRACKERS**

Sandwiched cookies and crackers occupy a significant place in the biscuit market. Typically, two identical biscuits (base cake) contain a layer of sweet or savory cream, peanut butter, or processed cheese. Sometimes the base cakes are dissimilar in shape and color. Sandwiched biscuits may be enrobed with
chocolate or compound coating to further improve appeal.
The sandwich may be formed from wafer sheets, in which case it may have multiple layers of cream between wafers, forming a "book."
The same type of cream may be deposited on a biscuit base, but with no topping biscuit before chocolate enrobing.
The weight of the cream is usually around 30% of the creamed sandwich, but amounts within a range of from 20% to 40% can be found. The thickness of cream is readily seen when the biscuit is picked up.
The sandwching is done by applying the filler with multinozzle depositors.
The depositor head may be low and travel with the biscuit in a continuous motion, or the head may be fixed and the biscuits moved intermittently. This system relies on the deposit breaking away from the nozzle as the latter is raised, so the cream must be quite fluid and the biscuit relatively heavy if a clean operation is to be achieved. Suction systems have been devised to hold the biscuits down where necessary. The biscuits are then moved to a "topping" station where the top biscuit is pressed on to make the sandwich.
The newer systems use extruded and wire-cutting machines to measure and deposit fillers. After being pushed out of a nozzle of appropriate shape, the cream from the hopper is deposited onto the base cake, and is then separated from the nozzle with a wire. Machines of this type operate in a continuous motion that extracts a biscuit from a stack feed and places it onto a pinned chain. The biscuit is transported under a rotating nozzle arrangement that is synchronized so that the nozzle and biscuit coincide. The creamed base moves on to a topping station where a top biscuit is pushed on and the two are pressed together under a wedge or roller.
In most cases, sandwiched biscuits are held in a cooling tunnel to set the filler before the biscuits are packed or processed further.
When cooling is done, it should be minimal so as to effect the desired firmness of the cream on the hottest day. Cooling air temperatures should be adjusted so that the biscuits are not cooled to below the dew point; otherwise, condensation will spoil the base-cake quality. It is best that the base cake is as cool as possible before creaming, as cooling of creamed sandwiches is a slow process.
After the secondary process or cooling, most cookies and crackers (except for dump-packed ones) have to be presented in a controlled or stacked formation to wrapping machines.
Whatever form of package is used, the ultimate measure of contents is weight, but for practical reasons most prepackage measuring is done by volume (i.e., the length of a stack of biscuits) or count. The problem of biscuit stacking, therefore, is not only to present the biscuits to the packaging operation in the form in which they can be most conveniently handled, but to do so in such a way that there is an acceptable correlation between the volume (stack length) or count, and the eventual weight of the pack.
In many countries, biscuit packages have to contain a guaranteed minimum weight. Since exact weight is normally impossible, it is in the manufacturer's interests to ensure that the packages contain only 1-2% more weight than is stated on the packet. One objective of efficient biscuit stacking is to ensure that this "give away" of actual weight over guaranteed weight is kept as small as possible.

**BISCUIT PACKAGING**

The objective of packaging is to collate the biscuits in groups of suitable size and to protect them so their flavor and appearance are preserved for as long as possible. The package also allows the display of information about type, weight, contents, price, age, and so forth, which may be required by law, and whatever graphic designs that may be considered attractive to customers so as to promote sales.
The primary pack is the moisture proof unit used for selling cookies and crackers to consumers. Secondary packaging consists of corrugated cardboard boxes or cases that are used for packing 12 or 24 of those packs for ease of storage and transportation.
Primary packages are of only a few basic types. The wrapper may be rigid in the form of a tin or plastic box, or more commonly, in the form of a flexible material that is sealed after the biscuits have been placed in it. Some biscuits are collated and placed into preformed bags and then heat-sealed. Packaging machines have become a necessity for cookie and cracker production plants because they increase throughput and reduce labor costs. However, automatic handling of biscuits and the relatively close tolerances required by wrapping machines in respect to biscuit size to achieve satisfactory pack seals and net weight mean that careful attention has to be paid to the entire production line. The malfunctioning of packaging equipment is probably the greatest cause of production slowdown in the bakeries.