

The Science of Baking

The Science of Baking – Structured Study Notes

1. Overview

Baking is a controlled chemical process that transforms a mixture of raw ingredients into a cohesive, flavorful, and often airy final product. Success depends on the interplay of **ingredients**, **temperature**, **time**, and **technique**.

2. Core Ingredients & Their Functions

Ingredient	Primary Role	Key Chemical Contributions
Flour	Structure	Provides gluten (proteins gliadin & glutenin) that forms a network when hydrated and mixed.
Water / Milk	Hydration & Dissolution	Activates gluten, dissolves salts & sugars, creates steam during baking.
Sugar	Sweetness, Browning, Moisture Retention	Caramelizes (Maillard & caramel reactions) and retains water (hygroscopic).
Fat (butter, oil, shortening)	Tenderness, Flavor, Leavening aid	Coats flour particles, limits gluten development, creates steam, contributes to crumb softness.
Leavening Agents	Gas production ? rise	Yeast (biological fermentation ? CO? + ethanol). Baking soda (NaHCO?) reacts with acid ? CO ?. Baking powder (baking soda + acid + filler) releases CO? in two stages (wet & heat).
Eggs	Structure, Emulsification, Leavening	Proteins coagulate, lecithin emulsifies fat & water, air incorporated during beating expands in heat.
Salt	Flavor, Gluten regulation	Strengthens gluten, slows yeast activity, balances sweetness.

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Ingredient	Primary Role	Key Chemical Contributions
Add-ins (nuts, fruit, chocolate, spices)	Flavor & texture	Mostly inert; may affect moisture and fat balance.

3. Key Chemical Processes

3.1 Gluten Development

1. **Hydration** – Water dissolves gliadin & glutenin.
2. **Mixing/Kneading** – Proteins link, forming an elastic network.
3. **Resting** – Allows network to relax, improving extensibility.

Result: Elastic dough that can trap gas bubbles.

3.2 Leavening Reactions

Agent	Reaction (simplified)	Temperature Trigger
Yeast	$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$	Active at 20–35°C; accelerates >30°C
Baking soda	$NaHCO_3 + H^+ \rightarrow Na^+ + CO_2 + H_2O$	Immediate when acid present; also at >50°C
Baking powder (single acting)	$NaHCO_3 + \text{acid} \rightarrow CO_2 + H_2O$	Moisture
Baking powder (double acting)	First: moisture; Second: heat (~70–80°C)	Dual release

3.3 Maillard Reaction & Caramelization

- **Maillard:** Reducing sugars + amino acids → brown pigments & complex flavors (140–180°C).
- **Caramelization:** Thermal degradation of sugars → sweet, nutty notes (170–200°C).

Both contribute to crust color, aroma, and taste.

3.4 Starch Gelatinization

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- Occurs at 60-70°C. Starch granules absorb water, swell, and become viscous, stabilizing the crumb and trapping gases.

3.5 Protein Coagulation (Eggs & Flour)