Biscuit Checking

A discussion of the checking mechanism and process prevention techniques

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Abstract

Biscuit checking is a source of breakage that occurs after the biscuit is baked and packaged. Because the breakage occurs after the biscuit is produced it can be difficult to monitor in this quality issue during real-time during production. As a biscuit bakes, moisture and stress gradients develop which will eventually come to equilibrium. How these gradients develop and equilibrate determine how much checking is caused. Optimizing processing parameters such as baking profile and cooling rate minimize the formation of gradients and maximize pre-transition equilibration. This presentation gives an outline of how each unit operation, from mixing to post conditioning, can contribute to this phenomenon. A case study is discussed.
Hairline cracks formation as a result of internal stresses

Usually occurs after manufacturing (>3 weeks)

May start immediately after baking with small fractures that may not be visible, growing gradually to become visible over time

Not to be confused with mechanical breakage
What is Checking?
Checking is caused by...

Moisture gradients within product structure
High moisture content
Non-uniform piece weight
Rapid and aggressive cooling
Baking time, temperature and oven humidity
Formulation
What is Checking?

*Checking Mechanism*

Moisture migration

- Low Moisture
- High Moisture
- Moisture migration

During Post Conditioning

- Moisture equilibrium
  - Center shrinks
  - Edges expand

Internal Stresses

CHECKING
What is Checking?

*Checking Mechanism*

Micro-fracture (not visible) → Gradual Growth → Visible Checking

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Mixing

Key Variables

- Ingredient Quality and Temperature
- Ingredient Scaling and Delivery
- Formulation
- Ingredient Order of Addition
- Mixing Time
- Mixing Speed (RPM)
- Final Dough temperature
Mixing

**Formulation**

- **Baked products** are categorized by the balance of flour, water, fat & water.

- **Cookies**
  - High levels of sugar & fat, low levels of flour & water
  - Dough is less elastic and less structured due to lack of gluten development
  - Minimum gelatinization

- **Crackers**
  - High levels of water & flour, low levels of sugar & fat
  - Dough is elastic and develops firm structure caused by gluten development
  - Maximum gelatinization
Mixing

Typical Mixing Sequence

Stage 1
Cream Up

Stage 2
Liquid Stage

Stage 3
Flour Stage

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Minimize dough weight differences across and along the conveyor belt.
If using gauge rolls, minimize sheet reduction level.
Uniform distribution of fresh dough.

Consistent Dough Weight = (Consistent Finished product moisture) + (Moisture gradient control)
Baking

Heat Flux Overview

The engineering definition of Heat Flux is the rate of energy transfer for a given surface area. In a Biscuit Oven, this can be thought of as how much heat enters the dough during baking.

• There are three basic types of heat in an oven:
  – Convection – heat from the air to the product
    • Air Temperature, Product Temperature, Air Flow rate, Air Specific Heat, Contact Surface Area
  – Conduction – heat the oven band to the product
    • Product Temperature, Band Temperature, Contract Surface Area, Material Composition
  – Radiation – heat from the inner bake chamber roof
    • Product Temperature, Radiating Surface Temperature, Emissivity, View Factor

• In any oven, we look at how heat moves through the oven & into the product:
  – Heat enters the oven from a source – usually a combustion burner
  – Heat moves through the oven – some reaches the product and some is lost
  – Heat enters the product and bakes dough into biscuit
Baking

Stages during biscuit baking operation

- Ovens are divided into different zones, but the principles of the baking stages remain the same
  - Stage 1: Structure Development
  - Stage 2: Moisture Removal
  - Stage 3: Color & Flavor Development
Baking

Effect of bake time on moisture gradients

Lowering moisture in finished product requires longer baking time

Reduce moisture gradient

Less expansion/contraction

Less checking

M. Mihalos, 2009
Post Conditioning

*Transitional stage and Moisture Gradients*

Transitional Stage
as a Function of Biscuit Moisture

Transitional state will depend on product moisture and moisture gradient. It is desirable to have the lowest moisture gradient possible.
Post Conditioning

Optimal Post Conditioning Process

Baking

Post Conditioning Process

Further Unit Operations

Cookie Temperature

$X > \text{Transitional Stage}$

$X < \text{Transitional Stage}$

At this stage, the product is in a soft phase, while equilibrating the moisture and stresses.

Since the product is in a fragile state, rates of cooling during the soft and transitional phases must be mild in order to ensure proper moisture equilibration.

The rate of equilibration is significantly reduced after the transitional state temperature is reached. Rates of cooling can be increased at this point in the process, without affecting the quality of the product.

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Case Study # 1
Cracker Breakage – M. Mihalos

Objective:
To reduce consumer complaints by developing a robust formula and process that minimize overall breakage

Causes of cracker checking/breakage
Non-uniform piece weight
Non-uniform moisture gradient
High levels of particulates
Insufficient level of dockering

Recommendations
Redesign the cutter so that all shapes have identical piece weights and more docker holes

Minimized the moisture gradient by:
  - Oven profile and humidity
  - Longer bake time
  - Lower target moisture

Reduced level of particulates

Adding dockers assists removing moisture from the interior of a biscuit during baking
Case Study # 2

Cookie Breakage – J. Rodriguez

Objective:
Decrease amount of broken and/or cracked cookies by evaluate post conditioning handling and processing

Causes of cracker checking/breakage
Cooling temperature
Post conditioning handling devices

Average Basecake Temperature

Average Basecake Temperature (F)

Post Conditioning Time (mins)

Mondelēz International

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Case Study # 2
Cookie Breakage – J. Rodriguez

Recommendations
Avoid the use of any instrument or device that can alter the shape of the product.

Use higher cooling temperatures for conditioning the product out of the oven.
**Summary**

**Mixing:**
- Maintain consistent dough temperatures in mixing
- Maintain consistent mixing time from batch to batch
- Evaluate formulation: fat level, emulsifiers, dough improves, aeration and invert sugar
- More thorough blending of ingredients to counteract checking

**Forming:**
- Minimize dough weight difference across the conveyor belt
- Minimize sheet reduction using multiple gauge rolls
- Uniform distribution with fresh dough

**Baking:**
- Keep oven humidity as high as possible in the first half of the oven
- Slower bake times – use more of the oven
- Maximize band loading
- Maintain top & bottom temperatures/heat levels as equal as possible

**Post Baking:**
- Cool the product as slowly as possible. Use covered tunnels rather than open air conveyors
- Cool the product when possible in a humid environment
- Avoid sudden, very cool drafts
- Post bake shingling
Questions?
Jose Rodriguez is an Associate Engineer at Mondelez International working for the New Global Process Research & Development team. Over the last 3 years, Jose has been involved in a series of projects that have led him to attain technical expertise on post conditioning, baking, molding and other biscuit manufacturing processes. Rodriguez has a B.S. in Chemical Engineering from University of Puerto Rico with a specialization in Bioprocess.

Will Conway is a process development engineer at Mondelez International leading the applied heat transfer research and development program for the global process development team. William recently completed a master’s of science in chemical engineer from Manhattan College and has worked in biscuit process development for 6 years. William’s current responsibilities include developing process analytical technologies to further development of global process specifications, as well as designing novel baking processes for increased throughput and control.