BAKING SCIENCE & TECHNOLOGY

Science

Specialty Flours; Flour Testing
Overview
Specialty flours are very generally defined (from grains; not patent, clear, or straight grade wheat flour) and many of the ones commonly used in bakery products are described. Although many flour testing procedures are discussed in Science labs, an overview of many such processes are also described here.

Purpose
Most specialty flours are used in bread and roll products, although more are being introduced into sweet goods. This section is designed to introduce you to a wide range of specialty flours, emphasizing the influence they have on the baking process.

Objectives
After completing this section of the course, you will be able to:

- Compare and contrast refined grain, multi-grain, and whole grain ingredients
- Identify cereal grains and their products
- Differentiate and explain preparation methods for variety “flours”
- Contrast characteristics of various wheat (including ancient wheats), rye, and triticale products
- Distinguish product characteristics from other cereal grains
- Recognize pseudo-cereals and their products
- Identify gluten-free and functional-gluten containing ingredients
- Identify non-grain variety flours, and their unique characteristics
- Summarize attributes of physical, analytical, microbiological, nutritional specifications of flour
- Interpret data from rheological testing (farinograph, mixograph, extensograph, alveograph)
- Describe tests and results of nontraditional flour analysis (SRC, spread tests, rotational viscometer, and consistometer)
Specialty (Variety) “Flours”
Not refined / white flours from wheat
   Not patent, clear, straight grade from wheat
May or may not be whole grain
   Grain = _____________________
   Also called seed, berry, or kernel
May or may not be “flour”
   Could be meal or larger

Refined Grain Ingredients
Milled and separated
   Removed: some protein, fiber, minerals, phytonutrients / phytochemicals
May be enriched
   Should then be labeled “enriched”

Stone-ground Ingredients
Flour or meal
No definition
Primarily marketing tool

Multi-grain Ingredients
Per US FDA Advisory
   _____________________ or more different grains
   Cereals or pseudo-cereals
       Not including seeds, roots, oilseeds, or legumes

Cereals
Seed heads of grasses (Poaceae or Gramineous family)
Starchy endosperm
Wheats, rye, rice, oats, barley, triticale, maize (corn), sorghum,
millets, teff, canary seed, Job’s tears, fonia, wild rice
Pseudo-cereals

Seed heads of number of different species of plants, not belonging to grass family

Not including legumes or oilseeds

Endosperm is mostly __________________________, like cereals

Amaranth, quinoa, buckwheat

Whole Grain Ingredients

Entire kernel

Contains all the pieces of the grains

Does not include hull or husk

May or may not be milled (ground or cracked)

Particle size is not significant in deciding whether or not an ingredient is whole grain

AACC International definition

Shall consist of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components (the starchy endosperm, germ and bran) are present in the same relative proportions as they exist in the intact caryopsis
Whole Grain Ingredients Continued

Whole Grains Council definition

Contain all the essential parts and naturally occurring nutrients of the entire grain seed

If the grain has been processed the food product should deliver approximately the same rich balance of nutrients that are found in the original grain seed

Whole Grain Food Definition

AACC International definition

Must contain 8 g or more of whole grain per 30 g of product

Not a legal definition

No clear, accepted definition exists for all bakery products

I will focus on what ingredients count or qualify

 Flake / Flaked / Rolled Process

Flattened between smooth rollers

Generally whole grain

Pearled / Polished Process

Abraded (sanded) to remove outer layers

Using friction

Major point of controversy

Is it whole grain?
Stabilized Process

Heat treated to inactivate (some) enzymes

- Particularly lipase and lipoxygenase
  
  These enzymes speed oxidative rancidity (production of off-flavors)

- Other methods may be used instead of heat

Important for shelf-life of high fat products

Optional Pre-treatment of Grains

Only used on large pieces (such as cracked wheat), not flours

- Hydrated or soaked

- Steam or infrared cooked, then dried
  
  - Increased water absorption and retention
  
  - Reduced microbial and enzymatic activity
  
  - Softer texture and changed flavor

National Organic Program Standards (US)

100% organic

- Only organic ingredients

Organic

- 95% or more organically produced ingredients by weight

Made with organic ingredients

- 70% or more organically produced ingredients by weight

US FDA “Natural” Policy

“Natural” is not defined for bakery products, but policy statement issued in 1993

- Food contains no artificial or synthetic ingredients

- Food contains no added coloring, regardless of source
Challenges for Using Variety “Flours” / Ingredients
**Whole Wheat Flour**

Wholemeal (non-US term)

Goal is ________________ extraction

- Canada (and some other countries) currently permits exclusion of 5% of the wheat kernel (≠ whole grain)

Usually HRW, HRS, HW wheats

“Graham” flour usually from soft wheat

Coarse to fine to ultrafine flour

Names are only general descriptions of particle sizes

End-users need to examine sieve data

What changes with particle size differences?

Produced by separate mill flow

No reduction rolls or purifiers

Or the mill blends all streams

Reconstituted / recombined

**Whole Wheat**

Good source of

- Insoluble fiber
- B-vitamins
- Antioxidants / Vitamin E
- Miscellaneous phytonutrients

**Whole Wheat Ingredients**

Vary by particle size

- Crushed wheat
  - Largest, slightly flattened, contains fines
- Cracked
  - Angular, smaller, less fines
- Steel cut (chop)
  - Smaller and more uniform than cracked
Whole Wheat Ingredients Continued

Vary by particle size continued

- Rolled or flaked
  - Thinner (flattened) and smaller than crushed
- Coarse to fine meals
- Coarse to fine flour

Whole Wheat Problems

Problems with bulk products (not just whole wheat)

- Segregation (during shipping)
- Bridging (during ________________)

Bulgur

Wet cooked (parboiled) wheat

- Predominately lightly pearled white or durum wheats

Dried

- May be whole, cracked or ground
- “Nutty” flavor
- Seed and/or nut replacement

Sprouted or Malted Wheat (Flour)

Start germinating - controlled

- Increases vitamin and mineral bioavailability
- Tastes sweeter / less bitter

Use wet or dry

- Low temperature drying

Freekeh (or Green Wheat)

Usually durum (could be any grain)

- Harvested prematurely, “green”
- Burned prior to threshing
- Rarely used in wholesale baking
Miscellaneous Wheat Products

Bran
Germ
  Probably defatted or stabilized
Aleurone
  Bran fractions

What is Aleurone?
- The aleurone cells are selectively isolated
- The cells are an excellent source of dietary fiber, essential vitamins and minerals

Durum Wheat
Very hard wheat, yellow endosperm
Less elastic gluten than common wheats
Semolina flour (more like meal) or durum flour
Or, any form used for common wheats

Ancient (or Heritage or Heirloom) Wheats
All are “covered caryopsis”
  - Have hull attached after harvest and threshing
Einkorn (small spelt)
Emmer (farro)
Spelt (dinkel)
Kamut®
Used in same diverse forms as common wheats

These photos represent the same sample, but with a micrograph, birefringence, and fluorescence.
Rye

Major differences from wheat

  Protein is irrelevant (to bakers)
  Not gluten-forming
  NOT “gluten-free”

Minimal __________ damage

Susceptible to sprout damage

High arabinoxylan (WE-AX) content

    Good health benefits

Flours sold by color (in US) and particle size

  Patent = “light” rye
  Straight grade = “medium” rye
  Clear = “dark” rye

What difference does this make?

Flours in Europe (and elsewhere?) sold by ash

Flaky meals

  From higher tempered rye

Pumpernickel

  Whole kernel meal (or flour)
  Is whole grain
  Malted / sprouted has milder flavor

Part of many “old world” levains and bigas

  Additional enzyme activity
Triticale

Man-made cross of wheat and ______________________

NOT “gluten free”

First serious effort at engineering a new crop

Not GMO (genetically modified organism), GE (genetically engineered) or bio-engineered

Used in same diverse forms as wheat and/or rye

Usually red, but available as purple and blue

Protein, ash, and fat levels frequently higher than wheat

Less / weaker gluten-forming proteins than wheat

Often high in protease

Corn (Maize)

Not gluten allergen

“Corn gluten” is not really gluten

Unique cereal

Very thin bran

Often incorrectly called “hull”

Germ is very large (13%)

Usually remove germ first

% fat is important specification

Yellow or white is most common

Blue, red, etcetera are also available

Whole grain meal and flour becoming popular

Many are stabilized

Special high amylose varieties are high fiber
Science: Specialty Flours; Flour Testing

Corn (Maize) Continued

Dry milling products sold by size

- Hominy
- Coarse, medium, and fine grits
- Coarse, medium, and fine meal
- Flour
- Bran

Used in batters and doughs and as “________________________”

- Does not hydrate well

Masa flour

- Whole kernels cooked in alkali, steeped, rinsed, ground, and
dried

- Used for tortillas and corn chips

Rice

Not gluten allergen

Rice is a “covered caryopsis”

- Has hull or husk in addition to bran, germ, and
  __________________________

  - Hull must be removed before rice is eaten

  - “Desired” end-product is generally intact, unbroken grain
    (head rice)

Unique in that oil and enzymes are distributed throughout bran, not germ

- Monitor lipid content for degree of milling
- Mostly unsaturated fatty acids

“Brown rice” can be red, purple, black, etcetera

- Generic term for whole rice
  - After hull has been removed
- Low fiber but high in other nutrients
- Often stabilized
Rice Continued

After polishing is called “white rice”

Broken kernels

  Second heads, screenings, brewer’s rice (usually not used by bakers)
  White rice meal / flour = pulverized broken grains (bran already removed)
  Brown rice meal / flour = pulverized brown rice (bran present)
    Stabilized
  Do not hydrate well

Long-grain, medium-grain, or short-grain?

  ______________________________-grain rice generally preferred for bakery products
    Moist texture
  ______________________________-grain dry / crisp texture

Common in gluten-free formulations

  Short- or medium-grain rice
  White or brown rice
  Waxy / sweet / sticky / glutinous rice
    Very low amylose (high amylopectin)

Rice bran (stabilized)

  Low fiber
  High fat

Puffed or crisped?

  Extruded form can be used in baking
Oats

Not gluten allergen (?)

Unique antioxidants

Avenanthramides

Oats are a “covered caryopsis”

Has hull or husk in addition to bran, ________________, and endosperm

Hull must be removed before oats are eaten

Called “groat” when hull is removed

Whole oat (whole grain)

Hull removal may occur before stabilization and/or kiln drying

Oats are generally stabilized

Remember: stabilization means heat treated to inactivate (some) enzymes

Oats have highest fat content of all cereals

Fat is mostly in the endosperm

Optional step for flaked products

Steam, then flake

Old fashioned (rolled oats)

Or cut, steam, then flake

Quick cooking (baby, minute oats)

Instant
Oats Continued

Flakes (rolled oats, oatmeal)

Thickness influences:
- Absorption characteristics
- Flake durability

Steel cut oats

Coarsely cut but not flaked

Meal or flour

Defined health claims (US FDA)

0.75 g β-glucan (soluble fiber) per serving

Definitions are written for oat bran, rolled oats (“oatmeal”), whole oat flour / meal

Barley

Gluten allergen

Most varieties have ______________________ closely attached
- “Covered caryopsis”

Some varieties hull-less or “naked”

Optional bleaching and polishing to remove blue aleurone

Barley is often included in lists of ancient grains (heritage or heirloom grains)

Pearling

- Abrasive scouring to remove hull
  - Pot barley (light pearling)
  - Pearled barley
    - Heavily pearled
    - Approximately 35% extraction

Larger pieces (as used in some bakery products) require more pearling

Challenge – how much pearling allowed for whole grain?
Barley Continued
Flakes (same as oats)
   Old fashioned or flakes
   Quick-cooking or baby
   Instant
Meal
Flour
Malted barley flour
   Carefully germinated, fermented, dried and ground
   Used as an enzyme supplement in flour, it is not counted as “whole grain”
Defined health claims (US FDA)
   0.75 g β-glucan (soluble fiber) per serving
High-fiber varieties available

“Ancient Grains”
Considered to be “unchanged by modern science and breeding technologies”
Ancient wheats, barley (already discussed), and grains we will now discuss

Millet(s)
Ancient (heritage or heirloom) grain
Not gluten allergen
Many types grown
   Pearl, foxtail, proso, and finger are most common
   Most types are naked, but some are covered
Very small, almost round, colored seeds
High in fat
   Mostly polyunsaturated
High ash
   Especially iron, copper, magnesium, phosphorous
Millet(s) Continued

Mild flavor
Whole, cracked, toasted, or puffed
Flour or meal
  Do not temper millet before milling, or tastes / smells “mousey”

Sorghum (Milo)

Ancient (heritage or heirloom) grain
Not gluten allergen
Food sorghums are generally white-pericarp, tan-plant
  Sweet flavor (?)
High protein, iron
Cracked, flaked, meal, flour
  Also popped
Relatively new to gluten-free formulations
  Especially whole grain

Teff

Ancient (heritage or heirloom) grain
Not gluten allergen
Extremely __________________________ cereal grain
  Whole or flour
Red, brown, or white
Sweet, molasses-like
  Can contribute chocolate or coffee note to flavor profile
Good nutritional value
  High protein and calcium
Canary Seed
Historically bird seed
Hairless varieties available for food use
  Very high protein
  No gluten, but may be similar proteins
  Small seed (similar to sesame seeds)
    Must have hull removed

Pseudo-cereals
Look like cereals (grains)
  High in __________________________
Genetically different
  Not grass family
Not gluten allergens
Used in multi-grain products
  Count as “grains”

Amaranth
Ancient (heritage or heirloom) grain
Small seeds in various colors
Whole, cracked, meal, flour, starch
Puffed or popped
  Topping or garnish
Sweet, earthy
  Contributes slight lactic acid flavor
Good nutrition
  High protein, good amino acid balance (high in lysine and methionine)
  Iron, calcium (magnesium, phosphorus)
  Fiber
Buckwheat

Ancient (heritage or heirloom) grain
No relation to wheat
Covered or hulled seed
  Pyramid-shaped seed
  Usually has hull removed
“Kasha” is dehulled, roasted seed (roasted groat)
  Sweeter than raw
Pearled, grits, flaked, meal, flour
  Intensely flavored
  Dark, gritty flour
Main ingredient in soba noodles
High in fat
  Mostly unsaturated
High lysine and threonine
  High-quality protein
  However, low digestibility?
Contains rutin
  Unique antioxidant

Quinoa

Ancient (heritage or heirloom) grain
Slightly smaller seed than millets
  Many different colors
High in saponins
  Removed by washing grain
Whole, flaked, or ground
Peanut-like flavor
Quinoa Continued

Excellent nutritional qualities

- High lysine
  - Contains all 8 (or 9) essential amino acids
- High fat (unsaturated)
- High iron, phosphorus, and calcium

Extremely popular

Limited availability
Non-cereal Options

Pulses (high protein and high fiber)
  Beans (fava, white, navy, pinto, etcetera)
  Legumes (chickpeas, lentils)
  Dry peas

Oilseeds
  Chia, flax, sunflower, etcetera

Potato products
  Flour, flakes, granules

Many others

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Processing Considerations – Flours

Gluten-forming

Non gluten-forming and gluten free
Processing Considerations – Other Forms

Gluten-forming, non gluten-forming and gluten free

- Will disrupt gluten network, even if gluten-forming
- Used mainly for texture, visual interest, nutrition
- Proper hydration (more important as particle size increases)
- Suggested max. 40%

Whole Grain Ingredient or Not?

Whole grain | Not whole grain | Must check processing
Flour Quality

Determined by wheat ("inherent flour quality")

- Genetic
- Variety

Environmental
- Soil conditions
- Temperature
- Rainfall
- Snow
- Etcetera

\( G \times E \approx 70\% \)

Determined by miller ("actual flour quality")

- Cleaning
- Tempering
- Length of flow
- Roll settings
- Sifters
- Extraction rate

How Do We “Control” Flour Quality?

Flour Specifications

- Communications between buyers and sellers

Objective

- To define the quality of the flour being used
- Not defining the quality of the finished product
Bakery Flour Specifications

Physical
- General description
- Wheat mix / class
- Color or “dress” (appearance)
  - Pekar, Hunter Lab
- Odor
- Foreign Material
  - Fragment (“frag”) count

Analytical
- Moisture
- Protein (measures nitrogen)
  - Kjeldahl or _________________
- Ash (measures minerals)
- Oxidation treatment
- Branscan or Fluoroscan
  - Digital image analysis
    - Uses visible light
    - Not measuring ash or minerals
      - Discriminates between bran and aleurone
- \( \alpha \)-amylase activity (starch liquefying)
  - Amylograph
  - Falling Number
  - Rapid Visco Analyzer (RVA)
Bakery Flour Specifications Continued

Analytical continued

$\alpha$-amylase activity continued

Falling Number Value of 442 sec means (assume bread flour):

Falling Number Value of 187 sec means (assume bread flour):

Falling Number Value of 255 sec means (assume bread flour):
Bakery Flour Specifications Continued

Analytical continued

β-amylase activity (saccharifying or sugar-making)
  Maltose value
  Gassing power
    Used more often to monitor yeast activity
    Rarely measured because is generally adequate amount in flour

Microbiological
  Mold
  Bacteria

Nutritional
  Enrichment
    “Yes or no” because quantities set by laws

Functional
  Uniformity
  Bake test

Rheological
  Rheology is the study of how materials deform, flow, or fail when force is applied
  Mixograph and Farinograph
    Both provide absorption and mixing characteristics
    Peak time
    Absorption
    Stability – tolerance – strength
Bakery Flour Specifications Continued

Rheological continued

Mixograph and Farinograph continued

Farinograph-E

DoughLAB

Mixolab

Extensograph and Alveograph

Both provide extensibility and resistance to extension information

Post (after) mixing

Extensograph
Bakery Flour Specifications Continued

Rheological continued

Extensograph continued

**Extensograph® Evaluation**

- **Resistance to Extension**
- **Extensibility**
- **Energy (Area in cm²)**
- **Ratio Number**

**Extensograph® Test — Different Flour Qualities**

- Strong flour, extensible and elastic dough
- Rigid, tough dough
- Poor extensibility
- Flour producing a wet, plastic, soft dough

**Extensograph® Test — Influence of Additives**

- Influence of increased amounts of ________?
Bakery Flour Specifications Continued

Rheological continued

Alveograph

Interpreting Alveograph Data

W is deformation energy or work
   Energy needed to make bubble as large as possible before bursting
   Indicates overall strength

L is abscissa to rupture
   Length from start of bubble formation to bursting
   Indicates extensibility
Bakery Flour Specifications Continued

Rheological continued

Interpreting Alveograph Data continued

P is overpressure

- Maximum pressure attained during inflation
- Generally called “indicator of dough resistance to deformation”
- Indicates strength

Ie is elasticity index

- Compares pressure after 200 cc air has been blown into bubble with the maximum pressure
- Indicates elastic resistance of dough

P/L is configuration ratio

- Approximate indication of alveogram shape

Protein quality / strength estimate

- Sedimentation (?)
- Gluten washing
- Hand
- Glutomatic
  - Gluten Index

SRC
Bake test

Solvent Retention Capacity (SRC) Profile

AACC International 56-11.02

Test based on exaggerated swelling behavior of specific polymer networks

- Glutenin proteins
- Damaged starch
- WE-AX
Solvent Retention Capacity (SRC) Profile Continued

Weight of solvent held by flour after centrifugation

Solvent retained
Percentage of flour weight on 14%MB

Combined pattern establishes “a practical” flour quality or functionality profile

50% sucrose
  Preferentially swells WE-AX

5% sodium carbonate
  Preferentially swells damaged starch

5% lactic acid
  Preferentially swells glutenin

Water
  Influenced by all flour components

Only one or two SRC solvents may be sufficient for specific application

Gluten performance index = (lactic acid SRC) / (sodium carbonate SRC + sucrose SRC)

Rheology of Fermenting Dough

Difficult to test ____________________________

Spread test (Cereal Chem. 1979. 56:141-143)

  Mix full dough, ferment, mold and place on smooth sheet
  Rest (proof)
  Measure width and height after 60 min
  Spread ratio = w / h
**Soft Wheat Flour Testing**

Alkaline water retention capacity (AWRC)

- AACC International 56-10.02
  - Good inverse correlation to cookie spread from baking tests
  - Measures amount of alkaline water held by the flour after centrifugation

Spread test - standardized method of baking cookie samples

- AACC International 10-50.05, 10-52.02, 10-53.01, 10-54.01
  - Very specific mixing, processing, baking, cooling, measuring procedures
  - Measure width divided by the thickness (height) of cookies
    \[ \frac{w}{h} \]
  - Very dependent on operator accuracy, but can be a reliable indicator of flour quality

**Rheological Analysis for Batters**

(or for fillings or icings/glazes or sauces or ....)

Two main choices

- Rotational viscometer (Brookfield)
  - Flour/water slurry or batter or ...
  - Report ____________________

- Consistometer (Bostwick)
  - Flour/water slurry or batter or ...
  - Report ____________________

**Rotational Viscometer (Brookfield)**

- Standard for fluid rheological measurements
- Uses mechanical (rotational) force to shear the fluid, and measures resistance to shear
  - Constant shape and temperature
Rheological Analysis for Batters Continued

Rotational Viscometer (Brookfield) continued

Consistometer (Bostwick)

“Simple” gravitational measurement of fluids

Common errors: level, temperature, dry

Flour -- What is REALLY Needed?

YOUR flour must conform to those measurable characteristics which are significant in terms of its intended end use

For information on additional tests, not commonly used, see the following