Yogurt Manufacture - 1

• Overview of yoghurt products and ingredients

Ranjan Sharma
2.5.3-2. Definition

Fermented milk means a food obtained by fermentation of milk or products derived from milk, where the fermentation involves the action of microorganisms and results in coagulation and a reduction in pH.

Yoghurt means a fermented milk where the fermentation has been carried out with lactic acid producing microorganisms.

2.5.3-3. A food that is sold as fermented milk or ‘yoghurt’ must:

a) be fermented milk or yoghurt as appropriate, or of fermented milk or yoghurt with other foods added; and
b) have a pH of no more than 4.5; and

2.5.3-4. Compositional requirements for fermented milk or yoghurt used as an ingredient

If a food contains fermented milk or yoghurt as an ingredient, that ingredient must comply with paragraphs 2.5.3—3(a) to (d).
FSANZ – Standard 2.5.3 –Fermented Milk Products – from 1 March 2016

2.5.3-5. Compositional requirement for phytosterols, phytostanols and their esters in yoghurt

*Phytosterols, phytostanols and their esters may be added to yoghurt only if:

a) the yoghurt contains no more than 1.5 g total fat/100 g; and
b) the yoghurt is supplied in a package, the capacity of which is no more than 200 g; and

c) the *total plant sterol equivalents content added is no less than 0.8 g and no more than 1.0 g/package.
Probiotics and prebiotics

- No legal definition
- Considered as “good”, “friendly” bacteria
- Live microorganisms - such as bacteria, yeasts and fungi - which in adequate amounts may have health benefits. Studies have shown they can improve digestion, help protect against disease and enhance immune function. Strains of *lactobacillus* and *bifidobacterium* bacteria are the most commonly used probiotics as they can survive the passage to the gut.
  - ABC cultures in yogurt (acidophilus, bifidobacterium, casei)
  - Benefits are strain specific
  - No health claims in Australia but statements like “naturally regulate and maintain your digestive system”
- Prebiotics are non-digestible food ingredients that can increase the activity of select “good” bacteria. Prebiotics naturally occur in bananas, asparagus, leeks, onions, garlic, chicory and wholegrains like wheat, rye, barley and oats. Inulin is commonly added as a prebiotic ingredient in yogurt.
Types of yogurt

- No legal definition
- Many different types/names loosely used
  - Set-style (Balkan style, Pot-set)
  - Strained (Mediterranean- or Greek-style)
  - Stirred (European-style)
  - Custard (French-style – naturally thickened)
- Fruited
  - Fruit on top
  - Fruit at the bottom – Sundae-style
  - Fruit throughout – Swiss-style
- Drinking yogurt
Types of yogurt

- Different types of yogurt available in various compositions and label claims
  - No-fat
  - Low-fat
  - 99.9% fat free
  - Full-fat
  - High protein
  - High fibre
  - Greek-style
  - Etc... etc..
Basic scheme for yogurt manufacture (large dairy)

1. Whole milk, Separated
2. Cream
3. Skim milk, Concentrate
4. UF retentate
5. Protein powder
6. SMP
7. Whey
8. Non-dairy additives

- Heating & homogenisation
- Fruit/flavour prep
- Flavour
- Filling
- Incubation
- Cooling
- Storage

- Cultures
- Incubation
- Cooling
- Storage
- Filling
- Cooling

- Stirred
- Fruit/flavour prep

- Set

- Chilled transport
  - Warehouse chiller
  - Supermarket chiller
  - Household fridge

- Consumer
Basic factory layout for yogurt manufacture

- Yogurt milk
  - PHE Chiller
  - Triblender
  - PHE, heater
- Standardised Milk storage tank
- Fermentation tank
  - Cooling yogurt
- Pasteuriser
- Preheat/regen
- Homogeniser
- Pasteuriser
- Holding tubes
- Filter
- Fruits
- Filler
- Yogurt base storage tanks
- Storage & distribution
Basic factory layout for yogurt manufacture
Yogurt processing steps and quality

- Milk with added ingredients
- Heating - 85°C/30 min, 90-95°C/5-10 min, 110-120/20-30 s
- Cooling to fermentation temp – 42-43°C
- Addition of start cultures (blend of S. thermophilus, S. bulgaricus + probiotics etc)
- Fermentation – 4-16 h
- Filling and packing
Factors affecting quality of yogurt

- Raw materials
  - Raw milk, skim milk, cream, sugar, cultures, milk concentrate, milk powders, fruit/fruit conserves, stabilisers, flavours and colours
  - All can contribute micro-organisms and chemicals that affect the quality
  - Changes in the source and supply will cause variation in factors that can influence shelf life
  - Partnerships with approved suppliers and agreed specifications are recommended
Factors affecting quality of yogurt

- Raw materials – Milk
  - Variability in protein, lactose, fat and microbial flora
  - Variability in breeds of cattle, season and region
  - Milking & storage conditions the farm

- Raw materials - cream
  - Depends on the quality of milk used for separation
  - Methods of handling before and after pasteurisation
  - Susceptibility to lipolysis due to high fat (potential for rancid taste)
Quality criteria for raw milk

- Low natural microflora
- Free from antibiotics, sanitising chemicals
- No contamination from mastitis milk and colostrums
- Free from rancidity
- Free from bacteriophages
- Free from hormones
- Stored below 5°C
Factors affecting quality of yogurt

- Raw materials – concentrates
  - Manufactured by either evaporation or membrane concentration
  - Quality of raw milk is important
  - Handling conditions before, during and after concentration
  - Heat stability of milk
  - Microbial flora should be low in thermodurics
  - Cooling rate and concentration factor can adversely affect the flavour and textural attributes
Factors affecting shelf life of yogurt

- Raw materials - fruits
  - Major areas of concern: microbiological quality, fruit ripeness, freshness, presence of pesticides & other agrochemicals

- Raw materials - other ingredients
  - Source of ingredient, approval of supplier, identification of critical control points (CCPs), and hygiene standards are all important
Role of milk solids

- Skim milk powder, skim conc., whey protein concentrates, Caseinates, etc.
  - Improves the gel strength and consistency of yogurt
  - Helps in controlling the whey/serum separation
  - Criteria for selection depend on the cost, availability and desired functionality
Heat treatment of yogurt milk

- Yogurt milk is heated at high temperature before starter inoculation
  - Destroys the potential competition for starter bacteria
  - Helps in enhancing the firmness of yogurt gel through denaturation of whey proteins and casein-whey protein interaction
  - Reduces the tendency for whey-serum separation by yogurt during storage
- Conditions: 85°C/30 min, 90-95°C/5-10 min, 110-120/20-30 s
Major changes in proteins during heat treatment of milk

Casein micelles based on Walstra & Jenness, 1984

Unheated milk

- Submicelle
- Protruding chain
- Calcium phosphate
- K-casein
- Whey protein (native)

Heating >85°C for >20 min

Heating at low pH (~pH 6.4-6.5)

Heating at high pH (~pH 7.0-7.1)

- Submicelle
- Protruding chain
- Calcium phosphate
- K-casein
- Whey protein (native)
- Whey protein (denatured)
Influence of homogenisation

- Mainly affects the fat globule size and the make up of the fat globule surface layers
- Helps in preventing cream separation during fermentation and cooling periods
- Improves the consistency and smoothness of yogurt
- Recommended for full-fat and low-fat yogurt
- Pressure: 20-25 MPa (200-250 bar) at 60-70°C
Yogurt networks - effect of heating and homogenisation

Kessler (1998) IDF special issue 199802
Yoghurt starter cultures

- **Growth temperature**
  - Thermophilic – *S. thermophilus, L. bulgaricus*
  - Mixed mesophilic/thermophilic

- **State of delivery**
  - Frozen
  - Freeze-dried (lyophilised)

- **Probiotic**
  - *L.casei, Bifidobacteria, L.acidophilus*

- **Direct set/Bulk**
  - Traditional cultures (undefined)
Delivery forms of starters

- Liquid, for propagation of mother culture (fairly rare)
- Deep-frozen, concentrated for propagation of bulk starter
- Deep-frozen, super-concentrated cultures in readily soluble form, for direct inoculation
- Freeze-dried, concentrated in powder form, for propagation of bulk starter or direct inoculation
Effect of incubation temperature on yogurt starter cultures

Yoghurt starter symbiosis

- *Streptococcus salivarius subsp. thermophilus* (ST)
  - Grows faster than LB
  - Produces acid plus carbon dioxide (help in the growth of LB)
  - Responsible for initial drop in pH (to ~5.0)

- *Lactobacillus delbrueckii subsp. bulgaricus* (LB)
  - More proteolytic activity than ST - produce peptides and amino acids (stimulate the growth of ST)
  - Helps to drop pH below 5.0
Starter growth with pH change and flavour development (2.5% starter addition)

Role of starter in flavour development

<table>
<thead>
<tr>
<th>Organism</th>
<th>Acetaldehyde</th>
<th>Acetone</th>
<th>Acetoin</th>
<th>Diacetyl</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. thermophilus</td>
<td>1.0 to 13.5</td>
<td>0.2 to 5.2</td>
<td>1.5 to 7.0</td>
<td>0.1 to 13.0</td>
</tr>
<tr>
<td>Lb. delbruekii subsp. bulgaricus</td>
<td>1.4 to 77.5</td>
<td>0.3 to 3.2</td>
<td>Trace to 2.0</td>
<td>0.5 to 13.0</td>
</tr>
<tr>
<td>Mixed cultures</td>
<td>2.0 to 41.0</td>
<td>1.3 to 4.0</td>
<td>2.2 to 5.7</td>
<td>0.4 to 0.9</td>
</tr>
</tbody>
</table>

Changes during fermentation

- Partial conversion of lactose to lactic acid (lactose fermentation)
- Decrease in pH
- Release of volatiles
- Growth of starter bacteria
- Aggregation of proteins and formation of a gel network
Lactose fermentation

- 20-30% lactose fermented by lactic acid bacteria using different pathways
- LAB are homofermentative, i.e. producing one major end product (95% lactic acid)
- Lactic acid
  - Conc. 0.7-1.0%
  - ST produces L(+) isomer and LB produces D(-) isomer (yogurt contains ~ 50-70% L(+))
  - D(-) isomer is metabolised slower level than L(-) isomer by humans
- Bifidobacteria produces 3:2 acetic:lactic acid
Major changes in protein during fermentation (heated milk)

- Repulsion
- pH reduction
- Attraction

Colloidal CaPO4

Network formation (e.g., yogurt)
Yogurt network formation
Yogurt microstructure

Skriver 1996 (KVL PhD Thesis)
Yogurt microstructure

TEM

SEM

Fat globules

Protein network

Lb bulgaricus

S. thermophilus

Skriver 1996 (KVL PhD Thesis)
Other changes during fermentation

- Slight proteolysis (1-2%) by starter bacteria is necessary for growth of the starter
  - L. bulgaricus more proteolytic than S. thermophilus
- Casein is the principal substrate but whey proteins may also be proteolysed
  - High levels of peptides and free amino acids (e.g. valine, proline, serine, histidine) in fermented milk
- Increased protein absorption
Cooling, fruit addition and packaging

- Rate of cooling
- Cooling temperature
- Aseptic fruit dosing and fruit quality
- Method of fruit addition
  - Mixed
  - Fruit on top
  - Fruit at the bottom
- Packaging material
Effect of fruit prep on syneresis and WHC

<table>
<thead>
<tr>
<th>Sample</th>
<th>Syneresis (%)</th>
<th>WHC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First day</td>
<td>Sixth day</td>
</tr>
<tr>
<td>Plane Yogurt</td>
<td>27.32±0.12^a</td>
<td>23.63±0.39^a</td>
</tr>
<tr>
<td>Apple Yogurt (7%)</td>
<td>22.61±0.36^b</td>
<td>18.96±0.02^b</td>
</tr>
<tr>
<td>Apple Yogurt (10%)</td>
<td>17.93±0.63^c</td>
<td>15.74±0.26^c</td>
</tr>
<tr>
<td>Banana Yogurt (7%)</td>
<td>20.31±1.64^e</td>
<td>18.36±0.13^d</td>
</tr>
<tr>
<td>Banana Yogurt (10%)</td>
<td>16.98±0.61^e</td>
<td>14.20±1.3^c</td>
</tr>
<tr>
<td>Strawberry Yogurt (7%)</td>
<td>24.33±0.96^b</td>
<td>21.51±0.15^b</td>
</tr>
<tr>
<td>Strawberry Yogurt (10%)</td>
<td>22.41±0.45^b</td>
<td>20.65±0.65^b</td>
</tr>
</tbody>
</table>
Effect of fruit prep on sensory properties

<table>
<thead>
<tr>
<th></th>
<th>Appearance and color</th>
<th>Body and texture</th>
<th>Flavor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
<td>Sixth</td>
<td>Tenth</td>
</tr>
<tr>
<td>Plane yogurt</td>
<td>4.31±0.14</td>
<td>4.40±0.12</td>
<td>4.21±0.14</td>
</tr>
<tr>
<td>Apple yogurt (7%)</td>
<td>4.70±0.21</td>
<td>4.81±0.14</td>
<td>4.60±1.5</td>
</tr>
<tr>
<td>Apple yogurt (10%)</td>
<td>4.21±0.43</td>
<td>4.32±02</td>
<td>3.81±0.17</td>
</tr>
<tr>
<td>Banana yogurt (7%)</td>
<td>4.61±0.12</td>
<td>4.43±0.15</td>
<td>4.82±0.14</td>
</tr>
<tr>
<td>Banana yogurt (10%)</td>
<td>4.10±0.26</td>
<td>3.91±0.12</td>
<td>4.20±0.31</td>
</tr>
<tr>
<td>Strawberry yogurt</td>
<td>4.81±0.12</td>
<td>4.80±0.09</td>
<td>4.41±0.2</td>
</tr>
<tr>
<td>(7%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strawberry yogurt</td>
<td>4.72±0.11</td>
<td>4.71±0.87</td>
<td>4.60±0.5</td>
</tr>
</tbody>
</table>
Effect of fruit prep on overall acceptability

Table 6. Effect of fruit pulp concentrations on overall acceptable scores properties of yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>overall acceptable scores</th>
<th>First</th>
<th>Sixth</th>
<th>Tenth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane yogurt</td>
<td>4.31±0.14^a</td>
<td>4.41±0.01^a</td>
<td>4.31±0.04^a</td>
<td></td>
</tr>
<tr>
<td>Apple yogurt (7%)</td>
<td>4.70±0.02^a</td>
<td>4.11±0.04^a</td>
<td>4.10±0.51^a</td>
<td></td>
</tr>
<tr>
<td>Apple yogurt (10%)</td>
<td>4.01±0.05^a</td>
<td>4.32±0.02^a</td>
<td>3.20±0.27^b</td>
<td></td>
</tr>
<tr>
<td>Banana yogurt (7%)</td>
<td>4.62±0.04^a</td>
<td>4.30±0.14^a</td>
<td>4.01±0.09^a</td>
<td></td>
</tr>
<tr>
<td>Banana yogurt (10%)</td>
<td>4.12±0.06^a</td>
<td>3.91±0.22^a</td>
<td>3.50±0.21^b</td>
<td></td>
</tr>
<tr>
<td>Strawberry yogurt (7%)</td>
<td>4.80±0.11^a</td>
<td>4.90±0.09^a</td>
<td>4.71±0.12^a</td>
<td></td>
</tr>
<tr>
<td>Strawberry yogurt (10%)</td>
<td>4.61±0.11^a</td>
<td>4.81±0.77^a</td>
<td>4.72±0.15^a</td>
<td></td>
</tr>
</tbody>
</table>

Yousef et al. 2013
Packaging, storage and distribution

Quality of product during manufacture

Temperature

Light

O₂

Internal (Composition + Micro-organisms)

Mechanical (Shaking, tension, pressure)

Packaging material
Yogurt Manufacture - 2

- Product characterisation methods
- Common product defects and how to diagnose them

Ranjan Sharma
Measuring yogurt quality - consistency

- Stirred yogurt 20°C (distance/min)
  - At packing (20-22°C) - 8-12 cm
  - After cooling (4-6°C) - 5-7 cm
  - Supermarket (4-8°C) - 2-4 cm
Measuring yogurt quality - viscosity

Brookfield viscometer
Helipath drive and “T” spindles
Measuring yogurt quality - rheology

- Rheometer TA Instruments – AR G2
  - Tests are performed applying a small sinusoidal strain (or stress)
  - Able to detect small changes in yogurt structure (useful for quality and consistency)
Measuring yogurt quality - syneresis

- **Syneresis**
  - Leave yogurt on a strainer at refrigeration temperature for a fixed time
  - Measure amount of free whey

Kessler (1998) IDF special issue 199802
Syneresis in yogurt – effect of temperature during storage

Whole milk yogurt
Skim milk yogurt

Salvador and Fiszman, 2004
Measuring yogurt quality - Texture

- TAXT Plus
  - Use fixed weight to penetrate into the gel network
  - Measure the resistance/depth
  - Texture Profile Analysis (TPA)
TPA – Texture Profile Analysis

- Force
- Texture Profile Analysis calculations for Texture Expert Software
- Test Speed
- Post Test Speed
- 1st Compression
- 1st Withdrawal
- Wait
- 2nd Compression
- 2nd Withdrawal
- Fracturability is the force at the 1st peak (Force 3 in the TPAFRAC.RES results file)
- Hardness is the maximum force of the 1st penetration (Force 2 in the software’s TPAFRAC.RES results file)
- Force 1 in the software’s TPAFRAC.RES results file
- Note that the probe withdraws to and waits at the point where it first encountered the trigger force on the 1st Compression
- Length 1
- Area 1
- Area 2
- Area 3
- Area 4
- Length 2
- Springiness = Length 2/Length 1
- Gumminess = Area 2/Area 1 * Hardness (Force 2)
- Resilience = Area 5/Area 4
- Chewiness = Gumminess * Length 2/Length 1
Flavour compounds in yogurt

Four main categories:

- Volatile carbonyl compounds (e.g., acetaldehyde, acetone, acetaloin, and diacetyl)
- Volatile acids (e.g., acetic, propionic, and butyric)
- Non-volatile acids (e.g., lactic, pyruvic, oxalic, and succinic)
- Miscellaneous compounds (e.g., certain amino acids and/or constituents formed by thermal degradation of protein, fat, and lactose)
Volatile compounds in yogurt

- More than 90 volatiles identified
- Carbonyl compounds (30+) – e.g. acetaldehyde, diacetyl, propanal etc
- Alcohols (15+) – ethanol, propanol, butanol etc
- Acids (10+) – acetic acid, propionic acid butyric acid, etc
- Esters (5+) – methyl, ethyl, butyl acetates, etc
- Sulphur compounds (5+) – sulphides and disulphides, etc
- Hydrocarbons (4+) – heptane, nonane etc
- Aromatic compounds (10+) – benzene, toluene etc
- Heterocyclic compounds (10+) – furan, fufural, etc

Deterioration of flavour during storage

- Yogurt is prone to deterioration, especially at an ambient temperature, within a matter of days
- Microbial, enzymatic, or chemical reactions occurring within yogurt during storage may alter its physical, chemical, and microbiological structure, causing deterioration or spoilage
- Generation of volatile by-products leads to off-flavors and makes the product unsatisfactory for the tastes of consumers
- The evolution of volatile compounds can often determine the storage and shelf life of yogurt
A grainy texture during fermentation

- Reasons:
  - Yogurt set at higher incubation temperatures
  - Faster acid production from the culture as it metabolizes lactose and ferments it into lactic acid can shock the inherent dairy proteins in the yogurt

- Solution:
  - Try setting your yogurt at a lower set temperature with the same culture. You may be surprised at the results.
Quality defects - appearance/texture

<table>
<thead>
<tr>
<th>Defect</th>
<th>Cause of defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syneresis/whey separation</td>
<td>Low total solids, Over acidification, mechanical shaking of gel network, insufficient denaturation of whey proteins, incompatibility of dairy and non-dairy ingredients (inappropriate amount and/or type of stabiliser), too high incubation temperature, too low acidification (pH&gt;4.6)</td>
</tr>
<tr>
<td>Low viscosity/runny</td>
<td>Low total solids, insufficient heat treatment/homogenisation of milk, poor selection of stabiliser, too low incubation temperature, too low inoculation rate</td>
</tr>
<tr>
<td>Film or colony growth on surface of consumer packs</td>
<td>Growth of yeasts and moulds (poor pasteurisation and/or post processing contamination), unhygienic processing conditions in the factory</td>
</tr>
<tr>
<td>Long/roapy texture</td>
<td>Slime producing contaminants, too low temperature of incubation</td>
</tr>
</tbody>
</table>
## Quality defects - appearance/texture

<table>
<thead>
<tr>
<th>Defect</th>
<th>Cause of defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grainy texture</td>
<td>Improper mixing or homogenisation of dry milk ingredients; too high incubation temperature, too low inoculation rate</td>
</tr>
<tr>
<td>Mealy gluey texture</td>
<td>Excessive addition of milk powder</td>
</tr>
<tr>
<td>Gas or air bubbles in coagulum</td>
<td>Contamination with yeasts or coli forms; aeration during pumping, air leaks in pipelines</td>
</tr>
<tr>
<td>Nodulation/curdy flecks</td>
<td>Improper mixing of starter culture, localised fermentation, too rapid acidification</td>
</tr>
<tr>
<td>Defect</td>
<td>Cause of defect</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Unclean/low-acidic</td>
<td>Poor activity of starter culture</td>
</tr>
<tr>
<td>Fermented</td>
<td>Contamination by yeasts and coliforms</td>
</tr>
<tr>
<td>High acid flavour</td>
<td>Too rapid fermentation by starter culture due to high temperature or too high starter conc level</td>
</tr>
<tr>
<td>Grassy/feed flavour</td>
<td>Grassy/feed flavour from raw milk</td>
</tr>
<tr>
<td>Bitter taste</td>
<td>High proteolytic activity, too high starter inoculation</td>
</tr>
<tr>
<td>Rancid flavour</td>
<td>Fat degradation due to lipolytic enzymes (insufficient heat treatment)</td>
</tr>
<tr>
<td>Oxidised</td>
<td>Light, metal catalyst</td>
</tr>
<tr>
<td>Slow pH decrease</td>
<td>Starter culture more proteolytic</td>
</tr>
</tbody>
</table>
Summary - Best quality yogurt every time

- Use extremely clean equipment without residues of detergents or sanitisers
- Source the best quality milk and use a fully enclosed fermentation system
- Make sure that added solids (dairy and non-dairy stabilisers) are well-hydrated and completely solubilised
- Apply adequate heat treatment to denature whey proteins and destroy any residual bacteria
- Cool the milk to fermentation temperature (42-43°C) and add fresh (active) starter and allow fermentation under strict temperature controls without agitation or shaking
- Cool rapidly with uniform agitation or pumping (devoid of air) without exposure to atmosphere
- Add sterile (aseptic) fruits if required in a closed system and pack under an uniform pumping system
- Cool rapidly in a blast cooler to below 4°C
Thank you

- Contact us for further information:
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