Factors that influence fluid milk flavor

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The bottom line

• Competitive and expanding market: milk has a lot of competition

• What are the keys to success?

  • Make what people want to buy
  • Make what people want to drink

• Deliver target flavors to customers
Delivering target flavors

• Make what people want to buy
• To do this we need to:
  • Understand the product
  • Understand the consumer
Consumer importance scores for fluid milk

N=879 consumers
Kano graph of consumer desires for fluid milk

N=879 consumers
Key Values for Milk Consumers

Interviews with 60 consumers

**ATTRIBUTES**

- Quality of Life
- Self Reward
- Security

**CONSEQUENCES**

- Overall Health
- Comfort
- Habit

- Quality of Life
- Self Reward

- Overall Health
- Family
- Nutrition

- Security
- Self Reward

- Familiarity
- Comfort
- Productivity
- Flavor

**VALUES**
The fluid milk consumer

• Milk consumers want reduced fat, conventional milk that tastes great and is healthy
  • Gallon/half gallon
  • extra protein, organic, other labels appealing

• Milk consumers associate unique values to milk consumption: habit, family, comfort
What influences milk flavor?

• Feed
• Raw milk quality
• Processing
• Packaging
Understanding product flavor: MILK
Some key questions

❖ What are the processing and package influences on milk flavor?
  ❖ Heat treatment
  ❖ Fat content
  ❖ Vitamin addition
  ❖ Packaging
Milk flavor at higher heat treatments

- **Trained panelists:** Cooked and eggy/sulfur flavors increase and sweet aromatic flavor decreases as heat treatment increases.

- **Consumers:** Liking decreases at temperatures > 85°C.
Trained panel profiling of skim milk 72 h post process with higher heat

Intensity

<table>
<thead>
<tr>
<th></th>
<th>81°C</th>
<th>85°C</th>
<th>95°C</th>
<th>140°C</th>
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<tr>
<td>Cooked flavor</td>
<td>4</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Sweet aromatic</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>cooked/eggy</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Consumer liking for skim milk higher heat treatments

Overall liking

N=100, 72 h post process

Decrease in consumer liking
At >85°C
Similar trend with 2% milk
Indirect and Direct Ultrapasteurization do not have the Same Flavor

Trained panel flavor profiles

- Eggy flavor is more intense (p<0.05) with skim milk
- Eggy flavor decreases with storage but differences in heat are consistent through 45 days at 4C (p<0.05)
Selected Aroma-Active Volatile compound characterization of milks processed by HTST, UP-DSI or UP-IND

The 3 milks are distinct by Volatile compound profiles, Consistent with sensory results

Lack of aroma
UP vs. HTST
Cooked
Overall aroma
UP vs. HTST

Lack of aroma
UP vs. HTST
Cooked
Overall aroma
UP vs. HTST

The 3 milks are distinct by Volatile compound profiles, Consistent with sensory results

HTST

UP-IND
Furfural (cooked/burnt)
2-acetyl-1-pyrroline (popcorn)
Dimethyl sulfide (sulfur)
3-Methylbutanal (malty)
2-butanone (cooked/plastic)
Benzaldehyde (nutty)
Maltol (sweet)

UP-DSI
Hydrogen sulfide (sulfur/egg)
Methional (potato)
Skatole (foul)
1-Octen-3-one (mushroom)

IND vs. DSI
Dimethyl disulfide (sulfur)
Carbon disulfide (cooked)
2-heptanone (cooked)
Diacetyl (milky)

Highest furosine
Sweet ← Sulfur →
Changes in flavor compounds during milk storage

Decreases in sulfur compounds
- Hydrogen sulfide (sulfur/egg)
- Carbon disulfide (cooked)
- Methional (potato)

Increases in oxidation compounds
- 2-Butanone (cooked/plastic)
- 2-Heptanone (cooked)
- Diacetyl (milky)
- 2/3-Methylbutanal (malty)
- Furfural (cooked/burnt)
- Hexanal (green)
- Dimethyl sulfide (sulfur)
- Phenyl acetate (cherry)
- 1-Octen-3-one (mushroom)
- Maltol (sweet)
Biplot of trained panel profiles and volatile compounds of skim milks

Similar results with 2% fat
Adult Consumer Liking of Milks

N=105 each consumer group

Overall liking skim
Overall liking 2%

Traditional HTST milk preferred
By adult consumers (p<0.05)

HTST
140C Indirect
140C Direct

Overall liking skim
Overall liking 2%

10 days post process
Adult Consumer Liking of Milks

N=105 each consumer group

Traditional HTST milk preferred by adult consumers (p<0.05)

THIS TREND IS THE SAME AFTER 45 DAYS POST PROCESSING

Overall liking skim
Overall liking 2%

HTST
140C Indirect
140C Direct

10 days post process
Attribute Importance Scores
Conjoint survey with 1163 milk consumers

Fluid Milk is a staple product - Price Matters Most
Consistent preference for HTST fluid milks

Pasteurization/Shelf Life Utility Scores

Conventional/HTST

Ultrapasteurized

Shelf stable/UHT

Pasteurization Method

Cluster 1 (n=309)  Cluster 2 (n=273)  Cluster 3 (n=308)  Cluster 4 (n=273)
### Ideal Levels for Different Clusters

N=1163 fluid milk consumers

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Understanding the consumer: MILK

Some key questions

❖ How does fat influence milk consumers?
Fat Content Utility Scores

“Breaking point” in acceptability at 2% milkfat for Clusters 1, 2, and 4

Increased fat = Decreased acceptability for Cluster 3

N=1163 consumers
Small differences noticed in skim (0.10%) by 2% of consumers.
Tasting Milk Fat Thresholds

Temperature had no effect on milkfat JND values (p>0.05)

- Skim (0.10%)
- 1%
- 2%
- Whole (3.3%)

n=60 consumers
Consumer Paired Preferences for Milks with Different Fats

Consumers do not prefer skim milk

N=172 consumers
Consumer Paired Preferences for Milks with Different Fats

More differences when Consumers are separated on fat content consumed

Skim milk: prefer 1 and 2% fat, reject higher fat

Low fat: reject skim, prefer whole

Whole milk: reject skim and 1% fat

N=60 consumers each group
The role of milkfat

• Follow up interviews with blinded tastings
  • Skim milk consumers: >2% fat milk was too heavy/thick
  • Lowfat consumers: skim was too watery, had no flavor, bad aftertaste, >3.25% was too rich
  • Whole consumers: >2% and up to 6% all had ideal flavor, thickness and aftertaste

• Fat plays a multimodal role in the sensory properties of fluid milk
  • Very distinct consumer preferences
Understanding product flavor: MILK

Some key questions

❖ Does vitamin addition impact fluid milk flavor?
Does vitamin fortification play a role in fluid milk flavor?

- Vitamins are added after separation and prior to pasteurization
- All pasteurized milk may be fortified with vitamin D (400 IU/946 ml)
- Reduced fat and skim milks are required to be fortified with vitamin A (2000 IU/946 ml)
- Fortified products must be within 100 to 150% of the label claims
- Studies with other foods have suggested that vitamin breakdown products can contribute flavor
Sources of Vitamin Concentrates

- Several suppliers
- Oil soluble and water dispersible forms
- Vitamin A, D, and mixtures of both
- Shelf life is 1 year at room temperature away from light

Does vitamin addition impact milk flavor?
Methods

- 14 commercial vitamin concentrates (vitamins A and D) (oil and water dispersible) obtained from multiple companies
- Trained panel profiling of concentrates
- Volatile compound analysis (SPME GCMS) with gas chromatography olfactometry (GCO)
- Sensory threshold testing of selected compounds in water, skim and whole milks
Trained Panel Aroma Profiles of Vitamin Concentrates

- Water soluble concentrates have higher overall aroma intensities
43 aroma active compounds were identified and quantified in the vitamin concentrates.

More compounds were detected in vitamin A and vitamin A and D concentrates (n=26) than in those with vitamin D alone (n=17).

More compounds were also detected in water dispersible vitamin concentrates (n=28) than oil soluble vitamin concentrates (n=15).
Threshold Test Compounds

- $\beta$-damascone (rose, violet)
- $\beta$-ionone (painty, floral)
- $\alpha$-irone (floral, sweet, green)
- $\beta$-cyclocitrinal (painty)
- $\beta$-phellandrene (mint, spice)
- isoamyl acetate (banana)
- 2,4-hexadienal (green, carroty)
- 2,4-heptadienal (fatty, carroty)
Orthonasal Thresholds for Vitamin Concentrate Compounds

Low thresholds in skim milk
Indicate possibility for off aromas
And flavors
Next Steps

- Manufacture of skim and 2% milk fortified with 6 representative vitamin concentrates at different concentrations
  - 4 levels + control for each vitamin (A, D, A/D) for skim and 2% fat
  - Trained panel profiling
  - Consumer difference testing

Fat standardization of raw milk + vitamin addition → Preheat (60°C) → Homogenization (1st stage 17.3 MPa, 2nd stage 3.4 MPa) → Pasteurization (73°C, 15 s)
Experiment 2: milk processing

- Standardized skim and 2% milk fortified with 6 representative vitamin concentrates at different concentrations

<table>
<thead>
<tr>
<th>Vitamin A</th>
<th>Vitamin D</th>
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<tbody>
<tr>
<td>0 IU (Control)</td>
<td>0 IU (Control)</td>
</tr>
<tr>
<td>1500 IU</td>
<td>200 IU</td>
</tr>
<tr>
<td>2000 IU</td>
<td>400 IU</td>
</tr>
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<td>2500 IU</td>
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<td>800 IU</td>
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<td>3000 IU</td>
<td>1200 IU</td>
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Each set of milks manufactured in duplicate

Vitamin A & D

<table>
<thead>
<tr>
<th>IU</th>
<th>IU</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1000/200</td>
<td>200</td>
</tr>
<tr>
<td>1500/300</td>
<td>400</td>
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<td>2000/400</td>
<td>800</td>
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<td>400/800</td>
<td>4000</td>
</tr>
<tr>
<td>6000/1200</td>
<td>8000</td>
</tr>
</tbody>
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Methods: Experiment II

- **Microbial quality**: coliform and aerobic plate counts
- **Proximate Analysis**
  - Fat/solids content- CEM & FTIR
  - Particle size distribution- Laser diffraction (Mastersizer 3000)
- **Vitamin Analysis**
  - Vitamin A in fortified fluid milk (AOAC 2002.06)
  - Vitamin D in fortified fluid milk (AOAC 2002.05)
- **Selected volatile compound analysis**
  - SPME GCMS with selective ion monitoring (SIM)
Methods: Experiment II

• Descriptive Analysis
  • Trained sensory panelists (n=8), each with > 150 h of experience, evaluated the milks at day 3 and 10 post-processing

• Consumer Difference Testing (n=50)
  • Conducted at day 10 post-processing
  • Triangle tests (ASTM E1885)
  • All vitamin concentration levels tested against the control: 60 difference tests conducted across across a 3 month period
## Results and Discussion: Experiment II

Consumer difference test results for skim milk with vitamin A

<table>
<thead>
<tr>
<th></th>
<th>Control vs. 1500 IU</th>
<th>Control vs. 2000 IU</th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>No. Correct</td>
<td>Significant at $\alpha=0.05$</td>
<td>No. Correct</td>
<td>Significant at $\alpha=0.05$</td>
</tr>
<tr>
<td>Premix concentrate</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Vitamin A Water Dispersible</td>
<td>(n=61)</td>
<td>22</td>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>Vitamin A Water Dispersible Rep 2</td>
<td>(n=50)</td>
<td>17</td>
<td>No</td>
<td>23</td>
</tr>
<tr>
<td>Vitamin A Sunflower Oil</td>
<td>(n=60)</td>
<td>22</td>
<td>No</td>
<td>20</td>
</tr>
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<td>(n=60)</td>
<td>22</td>
<td>No</td>
<td>21</td>
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Trained panelists detected low intensities of carrot/floral flavors in these milks
Beta-ionone detected at concentrations greater than sensory threshold (100-200 ppb) in these milks
Conclusions and Practical Application

• Vitamin fortification may impart off flavors to skim milk, fat containing milks probably not an issue due to the impact of fat on sensory detection thresholds.

• Vitamin A degradation products appear to be at highest potential for off flavors, manufacturers should be cautious about selection/use of water dispersable concentrates as well as storage of vitamin concentrates.
Understanding product flavor: MILK
Some key questions

❖ What about packaging?
❖ Standard is plastic (HDPE) jug or gabletop carton
❖ Both have flavor issues with fluid milk
## Ideal Levels for Different Clusters

**Shaded boxes are unique**

N=1163 fluid milk consumers

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</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>Paperboard Carton</td>
<td>Plastic Jug</td>
<td>Plastic Jug</td>
<td>Plastic Jug</td>
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<td><strong>Label Claim</strong></td>
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Cluster 1: Young, educated, least price sensitive, expresses concern about environment and farming practices.

N=1163 consumers
Milk packaging

- Translucent HDPE jug is most familiar
- **Problem**: milk is stored commercially in a refrigerated dairy case with lights
- **Problem**: milkfat and riboflavin* are sensitive to light
  - Oxidation of milkfat and protein side chains causes distinct off flavors
Light exposure of milk

- Milkfat will oxidize when exposed to light: **photolytic autooxidation**

- Riboflavin and other tetrapyrrololes are photosensitized in presence of light and generate free radicals that oxidize both fat and protein: **photosensitized oxidation**
Milk packaging and light oxidation

❖ Commercial dairy cases are variable in light source and lux intensity (500-2000lx)

❖ Fluorescent light more damaging than LED

❖ Package oxygen permeability and dissolved oxygen in the milk play a role

❖ For plastic jug, package type will have an effect
Light exposure of milk

- Multiple problems:
  - Vitamin degradation: riboflavin and vitamin A
  - Increase in volatile oxidation compounds
  - **Off flavors** called light oxidized or sunlight flavor, more specifically: plastic/rubbery, butterscotch, mushroom, cardboard, serumy
  - **Off flavors** are distinct with fat content and change with time/light exposure --- and heat treatment
Light oxidation flavor changes in translucent HDPE

![Graph showing flavor intensity changes over time for different light conditions.](image)
Total aldehydes in 2% milk during FL or LED light exposure

30% riboflavin loss
20% vitamin A loss
Summary

• Control of light induced off flavors of milk is complex
  • A lot of parameters impact the speed of off flavor development
    • Package – light block and oxygen permeability
    • Intensity of light exposure and wavelengths
    • Initial dissolved oxygen in the milk
    • Fat content of the milk
    • Heat treatment of the milk
Summary

• Flavor remains a fluid to final product quality parameter for milk – and flavor DOES matter to fluid milk consumers

• Milk components, processing and packaging impact milk flavor

• Understanding flavor, flavor formation, and flavor stability in conjunction with consumer and product research are key to maximize quality and product appeal
Acknowledgements
Acknowledgements