Iron sources and their properties with regards to Flour Fortification

8th Annual Southeast Asia District Conference
October 1-3, 2017

Annette Büter
Technical Applications Manager – Flour Fortification
Agenda

- Introduction to iron
- Iron sources in different applications:
  - Bakery
  - Pasta
  - Noodles
- Interactions of iron with flour improvers
Introduction to iron
Iron compounds for flour fortification

- Electrolytic iron
- Ferrous Fumarate
- Ferrous Sulfate
- Ferric Sodium EDTA
Introduction to iron – iron compounds

<table>
<thead>
<tr>
<th>Compound</th>
<th>% Iron Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolytic iron</td>
<td>97%</td>
</tr>
<tr>
<td>Ferrous fumarate</td>
<td>32%</td>
</tr>
<tr>
<td>Ferrous sulfate</td>
<td>32%</td>
</tr>
<tr>
<td>Ferric sodium EDTA</td>
<td>13%</td>
</tr>
</tbody>
</table>
Introduction to iron – iron compounds

% bioavailability

- Electrolytic iron: 50-75%
- Ferrous fumarate: 100%
- Ferrous sulfate: 100%
- Ferric sodium EDTA: 200-300%
Iron compounds in different applications

1. Bakery
Case study – Chile

Spots on hot dog rolls
Case study – Chile

Initial data

- Customer used ELCOvit 2035 RCH
- Dosage: 200 ppm, thereof 30 ppm iron from ferrous sulfate

Discussion

- Coarse ferrous sulfate can cause spots on bread crust
Case study – Chile

Formation of dark spots by a too coarse ferrous sulfate powder

Fine powder  Coarse powder
Case study – Chile

Different particle sizes of ferrous sulfate

![Graph showing volume percentage of fine and coarse powder against particle size. The graph indicates that the fine powder has 90% particles less than 100 µm, while the coarse powder has a higher percentage of larger particles.]
Case study – Chile

Discussion

- Coarse ferrous sulfate can cause spots on bread crust
- Granulation in all our premixes is very fine (90%<100µm)
- Batch was also delivered to other mills BUT
- No other complaints were filed
Case study – Chile

Cause

- Premix was kept in the feeder under humid conditions over a long period
- Agglomerates were formed

Action

- Sieving of flour
- Increase of free flowing agent in premix
Case study – Chile

- Free flowing agent – functionality
- Extremely fine particles ($\text{SiO}_2: \phi 13-20 \mu \text{m}$)
- Absorption of humidity
- Keeps particles at distance
Case study – Chile

Our recommended premix storage conditions:

- Low humidity (DRY)
- Out of direct light (DARK)
- Below 25°C (COOL)
Iron compounds in different applications

2. Pasta
Impact of iron sources on pasta

Trials in pasta to find out impact of different iron sources

- Spaghetti made from untreated hard wheat flour and water
- Flour was fortified with 60 ppm iron in all trials
- Control or reference: pasta with non-fortified flour

<table>
<thead>
<tr>
<th>Sample</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron source</td>
<td>Non-fortified</td>
<td>Ferric pyrophosphate</td>
<td>Ferric orthophosphate</td>
<td>Electrolytic iron</td>
<td>Ferrous fumarate</td>
<td>Ferrous sulfate</td>
<td>Ferric sodium EDTA</td>
</tr>
<tr>
<td>% Relative bio-availability</td>
<td>n.a.</td>
<td>21-74%</td>
<td>25-32%</td>
<td>50-75%</td>
<td>100%</td>
<td>100%</td>
<td>&gt;100%</td>
</tr>
<tr>
<td>% Iron content</td>
<td>n.a.</td>
<td>24%</td>
<td>26%</td>
<td>97%</td>
<td>32%</td>
<td>32%</td>
<td>13%</td>
</tr>
</tbody>
</table>
# Impact of iron sources on pasta

## Results of different iron sources in pasta

<table>
<thead>
<tr>
<th>Sample</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron source</td>
<td>Non-fortified</td>
<td>Ferric pyrophosphate</td>
<td>Ferric orthophosphate</td>
<td>Electrolytic iron</td>
<td>Ferrous fumarate</td>
<td>Ferrous sulfate</td>
<td>Ferric sodium EDTA</td>
</tr>
<tr>
<td>% Relative bio-availability</td>
<td>n.a.</td>
<td>21-74%</td>
<td>25-32%</td>
<td>50-75%</td>
<td>100%</td>
<td>100%</td>
<td>&gt;100%</td>
</tr>
<tr>
<td>% Iron content</td>
<td>n.a.</td>
<td>24%</td>
<td>26%</td>
<td>97%</td>
<td>32%</td>
<td>32%</td>
<td>13%</td>
</tr>
<tr>
<td>Pasta cooked</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appearance vs 0</td>
<td>Comparable</td>
<td>Comparable</td>
<td>Comparable</td>
<td>Brighter</td>
<td>Greyish</td>
<td>Much brighter</td>
<td></td>
</tr>
</tbody>
</table>
Iron compounds in different applications

3. Noodles
Impact of iron sources on noodles

 Trials in alkaline noodles to find out impact of different iron sources

- Noodles made from untreated low protein/ash wheat flour, salt, water, alkalines
- Flour was fortified with iron levels according to WHO recommendations
- Control or reference: noodles with non-fortified flour

<table>
<thead>
<tr>
<th>Sample</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron source</td>
<td>Non-fortified</td>
<td>Ferric pyrophosphate</td>
<td>Electrolytic iron</td>
<td>Ferrous fumarate</td>
<td>Ferrous sulfate</td>
<td>Ferric sodium EDTA</td>
<td>Ferric sodium EDTA</td>
</tr>
<tr>
<td>Added amount of iron - ppm</td>
<td>n.a.</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>
### Impact of iron sources on noodles

#### Results of iron sources in alkaline noodles

<table>
<thead>
<tr>
<th>Sample</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron source</td>
<td>Non-fortified</td>
<td>Ferric pyrophosphate</td>
<td>Electrolytic iron</td>
<td>Ferrous fumarate</td>
<td>Ferrous sulfate</td>
<td>Ferric sodium EDTA</td>
<td>Ferric sodium EDTA</td>
</tr>
<tr>
<td>Added amount of iron - ppm</td>
<td>n.a.</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Dough after 24h</td>
<td><img src="image1.png" alt="Image of dough" /></td>
<td><img src="image2.png" alt="Image of dough" /></td>
<td><img src="image3.png" alt="Image of dough" /></td>
<td><img src="image4.png" alt="Image of dough" /></td>
<td><img src="image5.png" alt="Image of dough" /></td>
<td><img src="image6.png" alt="Image of dough" /></td>
<td><img src="image7.png" alt="Image of dough" /></td>
</tr>
<tr>
<td>Noodles cooked</td>
<td><img src="image8.png" alt="Image of noodles" /></td>
<td><img src="image9.png" alt="Image of noodles" /></td>
<td><img src="image10.png" alt="Image of noodles" /></td>
<td><img src="image11.png" alt="Image of noodles" /></td>
<td><img src="image12.png" alt="Image of noodles" /></td>
<td><img src="image13.png" alt="Image of noodles" /></td>
<td><img src="image14.png" alt="Image of noodles" /></td>
</tr>
<tr>
<td>Appearance vs 0</td>
<td>Comparable</td>
<td>Comparable</td>
<td>slightly darker, less yellow</td>
<td>darker, less yellow</td>
<td>perceptibly darker, less yellow</td>
<td>comparable</td>
<td></td>
</tr>
</tbody>
</table>

---

Note: Images of dough and noodles are placeholders. Actual images should be provided for a complete understanding.

---

*Image credits: [Mühlenchemie](https://www.muehlenchemie.com)*
Examples of interactions with iron
Interactions of iron with flour improvers

Flour improver: Ascorbic acid
Interactions - flour improver & fortificants

Storage trials: Blend of ascorbic acid & different iron compounds

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mix 0</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
<th>Mix 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascorbic acid</td>
<td>100 ppm</td>
<td>100 ppm</td>
<td>100 ppm</td>
<td>100 ppm</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Ferric sodium EDTA</td>
<td></td>
<td>40 ppm Fe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous sulfate</td>
<td></td>
<td></td>
<td>60 ppm Fe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous fumarate</td>
<td></td>
<td></td>
<td></td>
<td>60 ppm Fe</td>
<td></td>
</tr>
<tr>
<td>Electrolytic iron</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>120 ppm Fe</td>
</tr>
</tbody>
</table>

Dosage ascorbic acid: average amount
Dosage iron: WHO recommendation
2 Storage conditions: 25°C / 50% r.H. (office Ahrensburg)
30°C / 80% r.H. (climatic chamber)
Interactions - flour improvers & fortificants

Mixes at the start of the trials
Interactions - flour improvers & fortificants

Mixes after 4 hours @25°C / 50% r.H.
Interactions - flour improvers & fortificants

Mixes after 24 hours @25°C / 50% r.H.
Interactions - flour improvers & fortificants

Mixes after 4 hours @30°C / 80% r.H.
Interactions - flour improvers & fortificants

Mixes after 24 hours @30°C / 80% r.H.
Interactions - flour improvers & fortificants

Ascorbic acid and iron – conclusion

Do NOT mix ascorbic acid and iron before adding to flour in hot and humid climates

- Ideally use two different feeders
- Once in the flour => too diluted to interact

At moderate conditions it seems possible
- Ascorbic acid degradation should be analysed
Summary

- 4 main iron sources are used in flour fortification
  - Different properties with different bioavailabilities

- Coarse Ferrous sulfate can lead to dark spots on bread crust
  - Follow premix storage instructions

- Iron sources can change the colour in cooked pasta and noodles
  - Higher bioavailable compounds lead to bigger changes

- Flour improvers should not be mixed with iron in concentrated form (before adding to flour)
  - Once in flour the components are too diluted to interact
Summary

IRON FORTIFICATION IS IMPORTANT

- to fight iron deficiencies and related diseases
- Several studies prove the nutritional effectiveness
- Several studies investigated impact of iron fortification on food
  - None to minor acceptable changes have been noticed
- Trials should be initiated before flour fortification standard is established in a country
Source: Food Fortification Initiative (FFI)

Our Vision:

Smarter, stronger, healthier people worldwide by improving vitamin and mineral nutrition.
Fortified flour – vitamins for a healthy life