The Impact of Processing Stages on Stability of Vitamin D3 fortified into Corn Flakes Using Nanoemulsions
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Introduction
Vitamin D is a fat-soluble vitamin that is known for promoting calcium absorption and thus bone health. Recent studies have shown vitamin D consumption is related to cognitive performance, certain cancers, and depression [1,2,3] due to its antioxidant characteristics. In the United States, 8.1% of the population is Vitamin D deficient; this is one of the highest prevalences of deficiency [4]. Because vitamin D is naturally found in only a few foods, fortification in food matrices can improve daily vitamin D intake.

Many RTE cereals in the market are fortified with vitamin D. However, there are challenges with vitamin D fortification due to poor water solubility, light instability, and high sensitivity to oxidizing agents. Thus, cereal manufacturers can add amounts up to twice as the label value in order to account for the losses during processing and storage [8]. This increases costs and creates waste. To optimize fortification, encapsulation strategies such as nanoemulsions (NE) have been developed to provide better dispersal of the vitamin in a non-lipid matrix. This technology utilizes ultrasonication (US), which is high frequency sound wave above the human hearing threshold, to create cavitation phenomenon to soy protein isolate (SPI), making it better emulsifier. With a combination of US and pH shifting, SPI can protect vitamin D and make it more stable and potentially more readily absorbed in the GI tract [5,6].

Furthermore, corn has abundant bioactive compounds that exhibit antioxidant capacity that can protect vitamin D from oxidative stress. A recent study shows total phenolic content significantly increased during toasting step of corn flake processing because the bound phenolics are liberated due to high temperature, thereby increasing soluble/active phenolics. [7] We hypothesize that the combination of nanoemulsion technique and phenolics in corn will even better protect vitamin D.

Objectives
Explore the potential for using soy-based nanoemulsions to fortify corn flakes with vitamin D3. More specifically, we propose to evaluate the impact of processing on stability of vitamin D3 at various stages of corn flake production process.

Methodology- Corn Flakes Making

1. Cooking: 15psi for 1 hour in a pressure cooker
2. Baking: 225°F for 50 min. Then, rest the dough for 30 min.
4. Toasting: 400°F for 80 sec.

Sample Preparation

Table 1: Addition of vitamin D in SPI NE into Corn Flakes

<table>
<thead>
<tr>
<th>Vitamin D (µg)</th>
<th>15µg (400IU)</th>
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</thead>
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25% RDA Target
4.5 μg

Typical Estimated Corn Flakes Consumption
56g (2 Cups)

Vitamin D SPI Nf
2.5µg/mg

Vitamin D SPI NE in 100g Corn Flakes
3.29mg/100g Corn Flakes

Table 2: Corn Flakes Ingredients

<table>
<thead>
<tr>
<th>Grinded Corn Grits</th>
<th>100g</th>
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<tbody>
<tr>
<td>Salt</td>
<td>2g</td>
</tr>
<tr>
<td>Sugar</td>
<td>6g</td>
</tr>
<tr>
<td>Maltose</td>
<td>4g</td>
</tr>
<tr>
<td>Water</td>
<td>200ml</td>
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</tbody>
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Treatments
Control (None)
VLD SPI (no sonication) 3.2 mg
VLD SPI NE (sonicated) 3.2 mg

Results

Figure 4. On the left is a scanning electron microscopy image of zein (principle protein of corn) nanoparticles. On the right is the cross-section showing internal cavities. [5]

Figure 5. Soy protein isolate (SPI) was modified with pH shifting (pH 12), sonication (5 min, 20 kHz) and neutralization. [6]

Figure 6. Protection of D3 upon UV exposure. [1]

Figure 7. Final Corn Flakes Products of three treatments. (A) Control. (B) Vitamin D in SPI nanoemulsion. (C) Vitamin D in SPI, no sonication.

Table 3: Soluble Phenolic Content Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>µg gallic acid equivalent/grams of corn sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>17.29</td>
</tr>
<tr>
<td>Treated Control</td>
<td>19.97</td>
</tr>
<tr>
<td>Treated SPI only</td>
<td>21.29</td>
</tr>
<tr>
<td>Treated SPI NE</td>
<td>27.82</td>
</tr>
<tr>
<td>Baked Control</td>
<td>27.75</td>
</tr>
<tr>
<td>Baked SPI only</td>
<td>26.13</td>
</tr>
<tr>
<td>Baked SPI NE</td>
<td>26.13</td>
</tr>
</tbody>
</table>

Future Research

- Vitamin D content analysis using reverse HPLC
- Accelerated storage test to examine stability of vitamin D
- Investigate combined effect of phenolics in corn and SPI nanoemulsion on the stability of fortified vitamin D in corn flakes
- Investigate bioavailability of SPI NE protected vitamin D

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