The Impact of Processing Stages on Stability of Vitamin D3 fortified into Corn Flakes Using Nanoemulsions

Yuju Rachel Chen, Nick Martsch, Emely Lopez, Hao Feng, Juan E. Andrade, and Nicki Engeseth

Department of Food Science and Human Nutrition, College of Agricultural, Consumer, and Environmental Sciences, University of Illinois at Urbana-Champaign

Introduction

Vitamin D is a fat-soluble vitamin that is known for promoting calcium absorption and thus bone health. Recent studies have show 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 prevalence of deficiency.[4] Because vitamin D is naturally found in only a few foods, fortification in food matrixes 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.

Sample Preparation

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

Vitamin D RDA	15µg (600IU)
30% RDA Target	4.5 µg
Typical Estimated Corn Flakes Consumption	56g (2 Cups)
Vitamin D SPI NP	2.5µg/mg
Vitamin D-SPI NE in 100g Corn Flakes	3.2mg/100g Corn Flakes

Table 2. Corn Flake Ingredients

Grinded Corn Grits	100g
Salt	2g
Sugar	6g
Molasses	2g
Water	200mL
Treatments	
Control (None)	
VitD SPI (no sonication)	3.2 mg
VitD SPI NE (sonicated)	3.2 mg

Methodology-Nanoemulsion (NE)

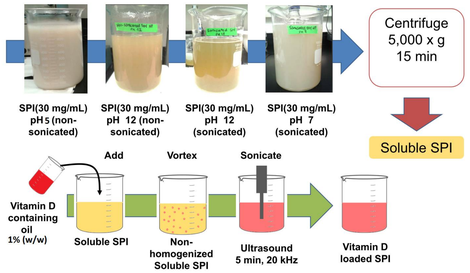


Figure 1. *Preparation of soy protein isolate nanoparticles using pH shifting and ultrasound.* [6]

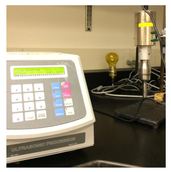


Figure 2. *Ultrasonicator and 20kHz probe.*

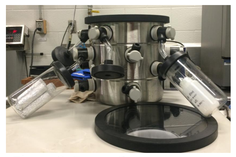
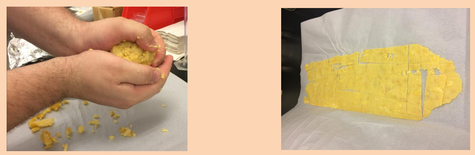


Figure 3. *Freeze Dryer*

Methodology- Corn Flakes Making

1. Cooking-15psi for 1 hour in a pressure cooker

2. Baking-225F for 50 min. Then, rest the dough for 30 min.



3. Knead. Flatten. Press. Cut.

4. Toasting-400F for 80 sec.

Results

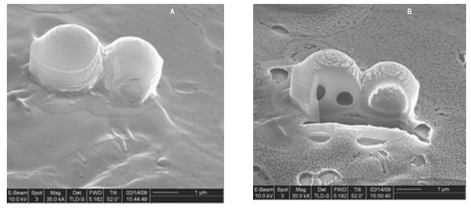


Figure 4. *On the left is a scanning electron microscopy image of zein (principle protein of corn) nanoparticles. On the right is the cross-section showing internal cavities. [5]*

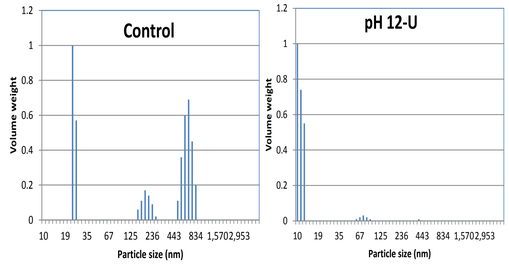


Figure 5. *Soy protein isolate (SPI) was modified with pH shifting (pH 12), sonication (5 min, 20 kHz) and neutralization. [5]*

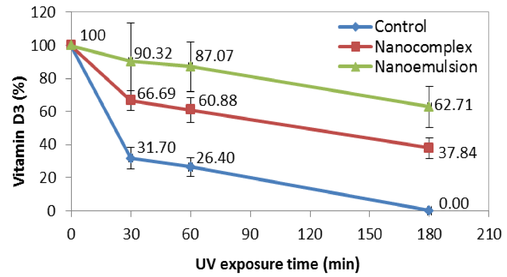


Figure 6*. Protection of D3 upon UV exposure.* [5]

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

Sample	(µg galic acid equivalence/grams of corn sample)
Toasted Control	17.29
Toasted SPI only	19.97
Toasted SPI NE	21.26
Baked Control	27.62
Baked SPI only	23.75
Baked SPI NE	22.18

Results

- Ultrasonication creates 1-10 micron particle size and cavities that can protect nutrients.
- Freeze drying may further retain nutrient.
- Combination of pH shifting and sonication cause reduction of particle size to <15nm, thereby improve solubility and makes an excellent emulsifier.
- Vitamin D is well protected in SPI NE against UV but is less protected in SPI, without sonication
- No visible difference in corn flakes final products of control, vitamin D-SPI NE and vitamin D-SPI alone treatments
- We expected higher soluble phenolic content in toasted flakes than in baked grits. However, the data indicate otherwise. More replicates and investigation are needed in the future.

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

References

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