Fat-free Milk?

Titanium Dioxide

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What is Titanium Dioxide (TiO₂)?

- A naturally occurring oxide, which is an odor-less powder with iron, chromium, vanadium or zirconium impurities
- Produced from the mineral ilmenite, and can take three forms:
 - **1.** Anatase (tetragonal crystal structure)
 - 2. Rutile (tetragonal crystal structure)

- Two polymorphs which are used as food additives
- **3.** Brookite (orthorhombic crystal structure)
- Food grade TiO₂ is manufactured from Ti minerals by:
 - **1.** A sulfuric acid-based process which yields anatase, rutile or a mixture of both, depending on reaction conditions
 - 2. Chlorine based process yielding only the rutile form
- World production of TiO₂ in 2014 exceeded 9 million tons!

Why is TiO₂ used as an additive?



Objects will appear a certain color because of how they reflect and absorb certain colors of light

For example, a red wagon looks red because it reflects red light and absorbs blue and green light

In an object that appears very white, all colors in the visible light spectrum are being reflected off uniformly, i.e., no color is being reflected more than any other color

Why is TiO₂ used as an additive?

- Milk is about 87% water and 13% solids
- In full-fat milk, there are several molecules that don't absorb color:
 - Fats, casein proteins, calcium complexes
- This causes milk to scatter and deflect light *uniformly*, resulting in the milk being opaque and appearing white to our eyes
- Sometimes milk can appear ivory or a slight yellow color:
 - **1.** The vitamin riboflavin has a greenish yellow color
 - 2. If the cow has a diet high in carotene (pigment found in carrots and pumpkins), it can also change the color of the milk

[2] https://www.thoughtco.com/why-milk-is-white-606172#:~:text=Fat%2Dfree%20or%20skim%20milk,more%20blue%20light%20than%20red.

Why is TiO₂ used as an additive?

- Fat-free, or skim milk, has its fat globules removed, and therefore has a bluish cast because of the *Tyndall Effect*
 - Light scattering by particles in a colloid or in a very fine suspension (fat free milk) which causes light to be passed through rather than be reflected
 - This causes blue light to be scattered much more strongly than red light, making the milk appear bluer in color
- Because of TiO₂'s light scattering properties, it is added to many food/drink products to enhance their white color and/or opacity.
- Most food-grade TiO₂ is around 200 300 nm in diameter which is the optimal size for ideal light scattering [1].

[1] H. C. Winkler et al, Journal of Nanobiotechnology (2018)

What else is TiO₂ added to?



- Other food or drink items that TiO₂ is added to are as follows:
 - Coffee Creamer: used to enhance white color
 - <u>Salad Dressing</u>: helps color the dressing and makes fat-free dressings have a creamier consistency
 - <u>Candy and Sweets</u>: used as pigment to make bright white
 - <u>Chocolate</u>: to provide a smooth texture
 - <u>Chewing Gum</u>: provides a sheen to the surface of the gum and helps with the bright white color
 - Sauces: used to help with opaqueness and consistency
 - <u>Vitamin Supplements</u>: to improve white color and block ultraviolet rays, giving them a longer shelf life







What else is TiO₂ added to?



- Some non-food items that TiO₂ is added to are as follows:
 - <u>Sunscreen</u>: nanoscale TiO₂ becomes transparent to visible light while absorbing UV light, causing a barrier to protect skin
 - <u>Cosmetics</u>: pigment-grade TiO₂ is used to hide blemishes and brighten skin, also allows for thinner coatings of make-up
 - Paints and Coatings: provides opacity and durability and increases the longevity of the paint
 - Paper: used to coat paper, making it whiter and brighter
 - Toothpaste: used as a white pigment in the paste
 - <u>Tampons</u>: used on tampon strings to make them look whiter





[3] <u>https://www.chemicalsafetyfacts.org/chemicals/titanium-dioxide/</u>

How does this affect YOU?

- How does this affect your health?
 - According to the FDA, if TiO₂ is used, it must be declared on the label and cannot exceed 1% by weight of the food
 - Specifications for food include a minimum purity of 99.0%
 - No current evidence that the amount we ingest is toxic or cancer-causing, but TiO₂ dust is a Group 2B carcinogen
 - Also, the EU and European Food Safety Authority (EFSA) has no longer authorized TiO₂ as a food additive as of August 7th, 2022, due to concerns over safety and potential cancer risks
 - Ultimately, the risks of TiO₂ depend on exposure, and more studies are needed to properly assess effects to humans

[4] D. H. Watson, Food Chemical Safety: Additives (2002)

Conclusions

- Titanium dioxide (TiO₂) is a prolific oxide which is used often as an additive in food and non-food products
- It is specifically added to fat-free milk and fat-free milk products to offset the Tyndall effect which gives the milk a blue color
- TiO₂ is most commonly used as a pigment, to color food and nonfood products white, help with opaqueness and consistency
- TiO₂ in food products is not believed to be toxic, but can contain contaminants, and there are not enough conclusive studies
- Maybe offer Santa a *full-fat* milk beverage with the cookies you put out this year



(almost)

Christmas!