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Titanium Dioxide in Food Products

Jacob Rop

Academy for Science and Design, 9 Townsend W, Nashua, NH 03063
Email: *jacobrop82[at]gmail.com*

Abstract: ***Titanium dioxide (TiO2), listed as food additive E171, is widely used in sauces, icing, chewing gum, and other consumer products for its light-scattering and semiconductor properties. Despite its prevalence, regulatory agencies disagree on its safety: the United States generally permits its use, while European regulators have taken a more cautious stance, including bans in some cases. This paper examines the scientific literature on TiO2 toxicity to evaluate whether current regulatory approaches are adequately protective. In vivo studies report genotoxic and cytotoxic effects following oral ingestion, including organ inflammation, liver cell necrosis, cardiovascular damage, kidney nephrotoxicity, and pre-neoplastic colon lesions, with children identified as a particularly vulnerable population. Conversely, other research finds minimal oral bioavailability and no observable cytotoxic effects, attributing earlier positive findings to unrealistic experimental conditions such as sonicated particles, unrealistic administration routes, and doses far exceeding typical human consumption. This paper argues that while TiO2 may be safe in moderate, realistic doses, methodological inconsistencies across studies make it difficult to draw firm conclusions, and the possibility of adverse effects at commonly consumed levels cannot be ruled out. Given this uncertainty, the paper concludes that TiO2 warrants continued research and stronger regulatory oversight rather than unconditional acceptance.***

Keywords: Titanium dioxide (TiO_2), E171, Food safety, Toxicity

1. Introduction

Titanium dioxide is regarded as "one of the most extensively utilized food additives (E171) in the food industry" (Hwang et al. 1). With this, one may think that titanium dioxides have been universally ruled as safe by international food safety organizations. This is not true, with the debate around the safety of titanium dioxide ongoing. Titanium dioxide is a mineral that has many properties that manufacturers have taken advantage of. It acts as a semiconductor and a light scatterer (Racivota 1). These elements make it advantageous to use in food products such as sauces, icing, and chewing gums, as well as care products like toothpaste and medicinal tablets. While it is used in a variety of products, its potential risks have not been completely ruled out. The debate over the significance of the effects of titanium dioxide has been ongoing, with some countries having come to their own conclusions. The U.S. generally accepts titanium dioxide while countries in Europe tend to be more cautious. Analyzing the issue through a scientific lens will lead to furthering our understanding of how titanium dioxides truly operate, and how they should be regulated. Not only will discussing this issue help agencies to create cleaner food products, discussing this issue will also help governmental agencies to improve the way they conduct and collect research so they can make better, more informed decisions with similar debates. While titanium dioxide is considered safe in moderation, evidence of genotoxic and cytotoxic effects from oral ingestion suggests increased need for regulation.

2. Literature Review

Various adverse effects of titanium dioxide have been identified using in vivo studies. Titanium dioxide is easily ingested since it is used in so many food products. Research has shown that "once titania pass the intestinal barrier, it enters the bloodstream and is transported to vital organs" (Racovita 10). After this point, titanium dioxide begins to take effect, but only at certain doses. Doses reaching "50, 100, and 150 mg/kg body weight" have been shown to "induce inflammatory responses and abnormal organ function" (Syed et al. 7).

The presence of these responses shows that ingesting titanium dioxide poses a health risk and those who ingest the most titanium dioxide are at highest risk for these effects. This would mean children are at a high risk since they have lower body masses and generally consume high amounts of products with this substance (Bischoff et al. 4-5). The corruption of biological processes causes a number of harmful side effects including inflammation in the stomach and intestines, liver cell necrosis, cardiovascular tissue damage, and kidney nephrotoxicity (Racovita 10-11).

Another study observed similar effects, but with smaller doses of titanium dioxide. In rats receiving titanium dioxide at up to 5 and 10 mg/kg a day, it was observed that pre-neoplastic lesions and colon cancer began to form (Bischoff et al. 26). In addition, titanium dioxide particles have been found to build up during continual exposure throughout a person's life (Warheit 14). This could lead to the worsening of organ damage as a person ages.

Despite similar findings from many studies, some researchers still insist that titanium dioxide does not cause significant adverse effects. Certain research has found that minimal amounts of titanium dioxide are absorbed into the body when it is ingested. The Australian food regulation agency FSANZ observed that the "oral bioavailability of titanium dioxide is less than 0.0013%, meaning titanium dioxide can hardly be absorbed in great enough amounts to produce any great effect" (Food Standards 19). This would invalidate the concern over whether those who consume products with the substance are at a serious risk level. It still does not prove that titanium dioxide is safe, and instead shows that it needs to be ingested in large amounts to have any real effect.

Additionally, it has been found that even when titanium dioxide has been absorbed, its low solubility means only small amounts even make it into the organs (Warheit 4).

Although this may show that titanium dioxide may not have an effect in trace amounts, it still does not allow for titanium dioxides to be considered harmless.

3. Discussion

3.1 Findings

In order to consider this issue, a study was conducted on human cadavers to see how titanium dioxide may alter them (Food Standards 19). This study had a particular focus on the genotoxic effects of titanium dioxide. No differential phenotypes or activations were found on these subjects. This means that the genes of the subject were not altered, and gene expression carried on normally. This has been attributed to the inorganic particles with titanium dioxide having low metabolic and immunological activity.

Other studies simply found that after oral consumption of titanium dioxide by rats and mice there were no observable cytotoxic effects (Winkler et al. 10). These findings are contrary to the results of others studies, and these differences may be attributed to a difference in the methods of experimentation.

3.2 Limitations of Past Findings

The relevance of studies on titanium dioxide has been one of the key aspects in the debate over how safe titanium dioxide is. Some scientists consider the conclusion that titanium dioxide is unsafe to be invalid, because some studies use titanium dioxide that has been sonicated. This suggests that titanium dioxide breaks down in the body. This is not entirely accurate, since the TiO_2 present in food is not sonicated and this method of experimentation does not consider food matrix effects (Food Standards 1). "While pre-neoplastic lesions in the colon were observed in a drinking water study with sonicated food-grade TiO_2 at 10 mg/kg bw/day, these findings were not replicated in two studies in which food-grade TiO_2 was administered" (Food Standards 20). This would mean that certain studies were not producing realistic results, and therefore could not be used as a guide in determining whether TiO_2 is harmful in real world applications.

Issues have also been found with the methods of administration. In one particular animal study, titanium dioxide was instilled into rodents until detrimental changes took place. This means that the researchers were searching for effects instead of trying to determine whether realistic doses of titanium dioxide could be harmful. Sometimes this process was fatal, with multiple rats being killed in the process. This method is different from human administration methods, where the administration of titanium dioxide is highly regulated, and can be considered much more realistic (Racovita 10).

Another major issue that has been found in studies pertaining to titanium dioxide is the quantity in which titanium dioxide is administered. A study exposing rats to 5 g/kg of titanium dioxide a day over two weeks, observed serious side effects (Racovita 11). This dosage has been estimated to be about 1000 times the normal amounts, with the standard human intake being between 0.5 and 14.8 mg/kg. This drastically alters the severity of the effects and could possibly invalidate the findings of the study. The unrealistic results which were "obtained employing extremely high doses of TiO_2 NPs and unrealistic routes of administration...should be interpreted with caution as preliminary findings to be validated under more realistic exposure conditions" (Iavicoli et al. 30).

3.3 Conclusion

Titanium dioxide is a controversial substance, with much research supporting its continual use, but much research also supporting its withdrawal from food products. Its prevalence in everyday products in areas like the U.S. and Australia means it will most likely continue to be used unless major scientific breakthroughs occur. It would have to be proven as harmful, since previous studies about its safety have been shown to be unrealistic. Although some of these studies can be viewed as exaggerated when discussing the issue of titanium dioxide, this does not completely rule out the possibility that titanium dioxide is detrimental, and further research must be done. Until then, the presence of any negative effect from a substance as common as titanium dioxide can be deemed dangerous, and it should be used with caution.

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