



Hazard versus Risk in Perceptions of Food Safety: The Case of Titanium Dioxide

ABSTRACT

This study was conducted to explore the contrast between hazard-based and risk-based assessments of food safety through a case study of the food ingredient titanium dioxide. Based on a hazard-based assessment, titanium dioxide has been banned by the European Food Safety Authority. In contrast, the ingredient is allowed within the limits set by the U.S. Food and Drug Administration. We addressed the following question: How do American consumers describe their perception of threat, or lack thereof, posed by titanium dioxide when informed or reminded that the color additive is common in the United States but banned in the European Union? Focus group participants shared their reactions to a brief video reviewing the titanium dioxide issue. These consumers were comfortable with a risk-based assessment, acknowledging that the potential for harm is low. Participants also identified a paradoxical situation in which they were overwhelmed or desensitized by the wealth of information about the many potential hazards they face yet were disappointed

by the lack of actionable information available. Based on these findings, practitioners of risk communication in the food industry would likely benefit from transparency by agencies regarding the distinction between hazard and risk when communicating about food safety policies. Dialogue among agencies such as the European Food Safety Authority and the U.S. Food and Drug Administration could help fill the information gap perceived by the study participants.

INTRODUCTION

All foods contain dozens if not hundreds of chemicals, either naturally present or intentionally added. Titanium dioxide, an often used but seldom discussed chemical found in many foods, acquired notoriety in July 2022, when a company including the chemical in its products was targeted in a class action lawsuit (12). Titanium dioxide, contained in thousands of foods across many product types, such as candy, toothpaste, and coffee creamer, has been approved by the U.S. Food and Drug Administration (FDA) as long as “it does not exceed 1 percent by weight of the food” (24).

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Critics claim that the FDA's policy was based on outdated research and that newer research establishes a link between the food additive and organ damage, including cancer (2). However, the FDA has not changed its recommendation.

The titanium dioxide case reflects the larger issue of basing policies on hazard versus risk. Simply put, a hazard-based approach to food safety is based on the presence or absence of a potentially dangerous agent in food, whereas a risk-based approach considers threat of exposure to a potentially dangerous agent that has an established threshold and to agents for which a threshold cannot be established (1). In the titanium dioxide case, the European Food Safety Authority (EFSA) concluded that a concern for genotoxicity of titanium dioxide particles cannot be ruled out. Based on this concern, the EFSA's experts no longer consider titanium dioxide safe when used as a food additive (5). Because this additive is considered hazardous, it has been banned in the European Union (4). Although the EFSA did not conclude that titanium dioxide is a definite health risk, it did not rule out the potential for the additive to possibly cause DNA or chromosomal damage (4). The FDA's position is that the risk posed by the current requirement is low; therefore, the FDA continues to allow its use at this level (24).

Our objective was to capture and interpret the words of American consumers as they describe their perception of the threat posed by titanium dioxide, particularly after they learn that the additive, although commonly used and approved in the United States, has been banned in the European Union. We addressed the following research question: How do American consumers describe their perception of threat, or lack thereof, posed by titanium dioxide when informed or reminded that the color additive is common in the United States but banned in the European Union?

Our rationale for conducting the study was not focused exclusively on issues related to titanium dioxide. Rather, we explored the influence an entity taking a hazard-based approach has on the risk perceptions of individuals living in a country or region where policies for the same hazard are made with a risk-based approach. This knowledge is valuable for risk communication practitioners charged with communicating food safety risks and other issues. These practitioners face an information paradox; they must provide consumers with more information about hazards within a context in which many consumers feel they already have too much information (19, 23). The importance of this research is evident in that more than a half-billion people become ill every year from contaminated food (26). This study addressed food safety specifically, and we generated conclusions and practical applications relevant to risk communication in other risk and hazard domains.

Our study began with a review of relevant literature on hazard versus risk decision making, particularly in the food industry. Here, we provide samples and interpretation of the words study participants shared about their perceived

danger of titanium dioxide and the conclusions we reached about the influence of hazard versus risk policy making. We also provide recommendations for risk communication practitioners.

Hazard versus risk in the food industry

Barlow et al. (1) asserted that food safety is not absolute. Rather, food producers should proceed with reasonable certainty that harm will not come to those who consume the food product as intended. Barlow et al. (1) explained that to reach reasonable confidence levels of food safety, both hazard-based and risk-based assessments are often used. Within the food industry, hazards are biological agents, microorganisms, toxins, and physical and radiological contaminants that are detrimental to health, and risk assessment provides estimates of the probability of negative health effects from contaminated foods (21). Focusing particularly on chemical toxicity in food, Kleter and Marvin (8) defined a hazard as any agent that can create a negative health effect. In contrast, a health risk assessment is an evaluation of the likelihood that a harmful effect will occur from exposure to a stressor and of the severity of such a negative effect.

Singh et al. (21) emphasized the importance of determining the severity hazards in all parts of food production. Verbeke et al. (25) explained that communication of the danger of these various hazards is difficult because consumers tend to overestimate the threat of some hazards and underestimate the threat of others. For example, Omari et al. (13) surveyed consumers in Ghana and found that they were notably more concerned about the unhygienic preparation and sale of food than about equally dangerous and prevalent risks involving chemical hazards related to ingredients, pesticides, or packaging. Sandman (17) suggested that factors unrelated to the hazard itself, such as whether exposure to the risk is voluntary or involuntary, natural or unnatural, and familiar or unfamiliar, impact the degree to which individuals perceive personal threat.

Hazard and risk assessments are critical to the food safety process. Overall, the risk analysis process includes a risk assessment with hazard identification at the scientific level, risk management at the policy-making and political levels, and risk communication directly to consumers (25). The way governments approach and implement policies has long been a primary issue in communications about food safety. Henson and Caswell (7) argued that the justification for food safety policies provided through risk communication is often a determining factor in whether public alarm or demand for regulation is assuaged. These authors also suggested that risk communication regarding food safety can influence trade policies with other nations. Powell (16) argued that risk communication policies, regardless of their scientific merit, cannot reassure the public unless these policies are communicated effectively.

Littlefield et al. (11) offered further support for the effectiveness of interactive communication about food safety. These authors enhanced understanding of scientific information related to food safety through a dialogue-based approach. They specifically established dialogue as a viable means for providing public education of food hazards and risks. Sellnow and Sellnow (20) found comparable results in their assessment of how instructional risk communication, particularly involving dialogue, can inspire the public to take recommended protective actions.

In previous research, a clear distinction has been drawn between processes for identifying hazards and for completing a risk assessment for food safety. Given the importance of interactive communication for providing both justification for and instructional communication about food safety, further research regarding how consumers reconcile contrasting messages regarding a hazard such as titanium dioxide is warranted.

MATERIALS AND METHODS

Focus groups were used to collect and observe participants' reactions to a brief video (2 min, 13 s) explaining the nature of titanium dioxide, its use in the United States, and its ban in the European Union (<https://www.youtube.com/watch?v=UuxiEWpXVKM>). The video, in the form of a television news story, was prepared by VERIFY, a subsidiary of the television corporation TENGA Inc., owner of 64 news brands in 51 markets (<https://www.tegna.com/about/trustworthy-impactful-journalism/>). The presentation was fact based and objectively explanatory in nature. Two food safety specialists reviewed the video to verify its accuracy and objectivity. Sources in the VERIFY news story included the FDA, the company mentioned in the lawsuit, the EFSA, the European Commission, and food safety expert Norbert Kaminski, director of the Institute for Integrative Toxicology (Michigan State University, East Lansing). Participants were not given any information in the video or any other phase of the study regarding the impact of removing titanium dioxide that might be apparent to consumers. After viewing the news story, participants were asked to share their level of confidence that titanium dioxide was safe to consume under the current FDA guidelines.

Participants

A total of 34 people participated in the focus groups from a pool of 43 people who were contacted. Three researchers working on this project used their personal and professional connections to email 38 potential participants. Convenience sampling was used to access actual consumers of the food ingredient central to the study (22). The remaining five people were recruited through snowball sampling by asking the original 38 potential participants whether they knew anyone else who might be interested in participating in the study. Participants had to be U.S. residents, >18 years

old, and consumers of candy or a person who served candy products at home. Of the 34 final participants, 18 self-identified as female and 16 self-identified as male. Participants self-identified their age as follows: 18 to 24 years ($n = 3$), 25 to 34 years ($n = 11$), 35 to 44 years ($n = 11$), 45 to 54 years ($n = 4$), 55 to 64 years ($n = 4$), 65 to 74 years ($n = 5$), and 75 to 84 years ($n = 1$). All activities involving human subjects for the focus groups were reviewed and approved by the University of Central Florida Institutional Review Board (IRB#CR00002402).

Procedure

Six focus groups were convened between 24 and 29 April 2023. Focus groups lasted 31 to 63 min (mean, 40 min). The time needed to play the news video clip was not included in the total time. Informed consent was obtained for each focus group participant. The focus groups were convened and recorded via Zoom technology. Focus group comments were transcribed by a professional transcription service between 2 and 7 May 2023. The focus group discussions generated 75 single-spaced pages of text. Transcription did not include audio transcription of the video clip played during each of the focus group meetings. Focus group facilitators were trained in best practices for Zoom meetings (27) as a communication channel for focus groups. Participants were asked to remain unmuted unless they had excessive background noise. All participants were required to have their cameras on. Participants were encouraged to use the hand-raising emoji while someone else was speaking to alert the facilitator that they wanted to speak next; otherwise, participants were free to talk at will. All facilitators reported no issues with interrupting, and all participants actively participated in the group discussion. No information was shared beyond the summary provided by the video. After watching the video, participants were asked about their level of concern about titanium dioxide, their willingness to continue consuming products including titanium dioxide, the nature of information they desired in such risk circumstances, and their trust in the FDA.

Analysis

The transcripts were analyzed qualitatively to identify key themes emerging from the participants. Two of the authors served as coders. The coders read the transcripts independently using a constant comparison method to determine the viability of existing categories and the need for further combination, recategorization, or establishment of new categories (10). The coders then met in person to share their coding subthemes and to identify areas where the themes could be combined or relabeled. Discussion continued until consensus was reached. Coders then selected representative examples from the transcripts for each subtheme.

TABLE 1. Thematic analysis of titanium dioxide perceptions

Theme	Related subtheme
Perceptions of severity	Indiscriminate
	Need more information
Uncertainty	Quality of information
	Quantity of information
Motives	Trusted
	Seeking confirmation
	Biased

RESULTS

The coding process revealed three primary themes and seven related subthemes (Table 1). The nature of each theme is described here, and representative quotations from the study participants are provided for each subtheme. Examples were selected based on their capacity to represent the discussion. Quotations are attributed to participants with two numbers: the focus group session and the individual within that session.

Perceptions of severity

Perceptions of severity emerged as a frequent theme in all focus groups. Few participants expressed alarm after watching the video. Instead, participants appeared indiscriminate in their perceptions of food-related risks or expressed a need for more information. Participant 4-6 was not able to discriminate among the potential dangers in processed food ingredients, saying, “I feel like it’s always coming out that there are artificial sweeteners or additives in candies and other things, and it’s just part of consuming things.” Similarly, participant 4-5 stated:

No. I mean I think we’ve already said that it [the video] just sort of let us know that the UK feels like it should not be in our food, but I think if you read any label you get to about the fourth ingredient and you don’t know what it is anyway. We wouldn’t eat anything because there are chemicals in everything. So, no, I don’t think we got enough information. It is interesting though as to why [the EFSA] would think that we can’t eat it, and we have this incredible FDA and yet they don’t seem to be too concerned.

Participant 1-3 agreed, saying the risks related to food are myriad:

So, I don’t feel I’m putting myself or my family in danger by consuming titanium dioxide. Also, having a previous career before getting in education in the food service industry, there are a lot of things I think that are in foods that are a lot more dangerous than the amount of titanium dioxide that’s actually in some of these products that are available.

Those who did express concern about titanium dioxide specifically did so out of concern for their children. For example, participant 3-2 said:

I definitely will be checking my kid’s toothpaste. She is a baby, and it is not colored so there is probably not anything in it, but I think kind of what 3-3 was saying earlier just making sure that more so that my kids are keeping away from it more. I kind of feel like for me it is a little too late.

Simply knowing the stated hazard and the fact that titanium dioxide is banned in the European Union was not enough information to heighten this participants’ risk.

The participants frequently shared a desire to obtain more information before altering their perceptions of the risk associated with consumption of titanium dioxide. Participant 6-5 expressed, “They were just saying, well, we can’t prove that it is, so just don’t consume it at all, which I feel like you need to do a bit more of a study before you ban something like outright.” Likewise, participant 4-6 stated:

I wish they would have gone more into how it affects people, the amount of people affected, and symptoms that people show. It kind of just felt like bait and switch headline. Like, it scares you, but it doesn’t really give much explanation of why you should be scared.

Participant 4-3 showed initiative regarding the need for more information saying simply, “I think I instantly just wanted to go to Google and learn a lot more.”

Uncertainty

Participants were also asked to assess the information they received and the sources in the video. Their responses focused largely on the fact that although they learned about the presence and use of titanium dioxide and that it has been banned in parts of Europe, they remained highly uncertain about the risk it posed. Participant 2-4 expressed frustration with the ubiquity of titanium dioxide and lack of clear focus in the information provided by saying, “I’ve only taken one chemistry class, but all the words sound crazy. So, for all I know, it could be in our water, or it could be in the chlorine. It could be in anything.” Participant 5-5 had a similar reaction:

I just don't think there was enough information and that could just be due to the fact that they said that more information needs to be gathered before even a solid conclusion could be made. So, that's probably part of it. But I just think that there wasn't enough detail on what the possible negative side effects could've been in order for me to honestly really care.

To counter uncertainty, Participant 6-2 suggested that another approach to information was needed:

I think the amount of information that we would need to be given would need to be like factual but also scary enough for people to be like, oh, dang. Like, I shouldn't be doing this because Americans and society just don't really care about small things like this in my opinion.

Participant 6-4 was less influenced by the information presented in the video and relied more on personal observation and experience to address the uncertainty, saying simply, "I definitely don't think it will change my consumption, and that is only because I haven't seen like harmful effects on my own body. So, it is honestly not hurting me that much."

Motives

When asked about their confidence in the agencies providing the information, participants were often supportive of the FDA. For example, participant 3-4 said, "I don't know enough about the process that the FDA goes through to verify things, and maybe that is naïve of me. But my general instinct would be to trust it because I can't do the research myself." In contrast, participant 5-1 expressed greater trust in the European Union:

As simple answer as it could be is I would probably trust the EU a little more than I would trust our own government just based of where the money would be coming from [company names mentioned]. All these guys are all American funded companies or yeah, American based companies. So, that's probably where their research is coming from if it's FDA backed.

Participant 4-2 had similar confidence in the European Union:

I feel like at least in safety trends the European Union has historically tended to be 3 or 4 years ahead of the United States, and so I am at least a little concerned. I don't know if it is concerned enough to stop eating [candy], but I am concerned.

Clearly, some respondents found the information provided not only insufficient but also questionable.

Although trusting, some respondents also emphasized the need for consumers to remain diligent in seeking additional content before making their decisions. Participant 6-4 emphasized the active role consumers need to play in making decisions about the foods they consume:

I kind of put the same stock in all studies from all of the governing bodies that are over food and drugs. ... It is not that I don't trust them [the EU], or I don't believe them, but I don't just like blindly believe them as well. I do the same thing with the FDA.

Participant 6-4 shared similar sentiments:

So, it just depends, but I trust them. I mean I think that they are a government agency, and they are responsible for making sure that people in Europe are safe, so they have credible people that are doing these things, but that doesn't mean that, as I think someone said, we should blindly trust them. You know, you should do some more work before you make a decision.

Although some participants expressed a combination of trust and personal responsibility, others emphasized the bias mentioned in participant 5-1's comparison between agencies in more vivid detail.

The objectivity of those within the agencies making policies about titanium dioxide were questioned by some study participants. Participant 1-5, for example, questioned the motives of those who are sounding the alarm about titanium dioxide:

To me, it's why are you putting out this information. What is your bias in this? What's your stake in this and then too, what are you basing the research on. ... I don't know and I just don't trust anybody with a Ph.D. behind their name. It seems credible, but I need more information about the person too. What do they study? Where are they currently researching at? What is their sort of bias too?

Participant 2-4 also expressed reservations about the bias of the agencies making decisions about the safety of titanium dioxide:

But some of it—just kind of thinking outside the box—I think some of that is cultural in terms of Europe banning something and America not. I just think that those officials look at European's banning stuff and they just automatically have this kind of bias perception of "Oh, great. Something else they banned and didn't fully research."

These concerns over bias were accompanied by further suspicion of motives.

In addition to questions of bias, some participants also emphasized the likelihood that participating agencies and the company mentioned in the lawsuit had a hidden agenda of some sort. For instance, participant 1-3 questioned the "true" role of titanium dioxide in food:

So, when I heard it, I was like, "Oh. There must be an addictive characteristic beyond sugar," which is one of the most addictive things in the world. But I said, "Oh. This must enhance or help kind of becoming addicted to it." That's why we're keeping it, so people will buy more of it.

Participant 1-3 was suspicious that monetary gain might have played a role in decision making by agencies:

There has to be an instance, or a reason, or multiple reasons I would hope that a large government body would ban a certain product for. Signs of hospitalization or something that definitely maybe hopefully biologists, and chemists, and all of these things got together like, we should probably bring this up because maybe it's for monetary gain.

Participant 5-3 had similar concerns asking, "Well, why did they not approve it there and approve it here? Is it being more business instead of health safety, that type of thing?"

“Information Paradox”

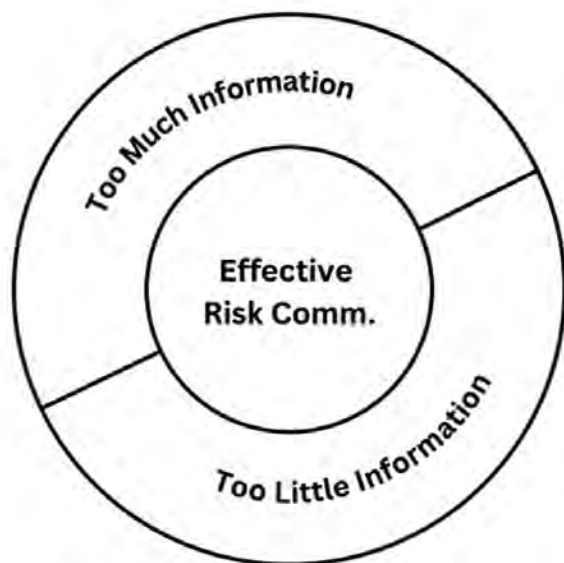


FIGURE 1. Information paradox.⁴

“Effective risk communication, situated at the inner of the two concentric circles, occurs by balancing two seemingly paradoxical demands situated in the outer of the two concentric circles: too much information that is perceived as unnecessary or ineffective for audiences and simultaneously too little information that is perceived as essential or effective for audiences (19).

Overall, discussion in five of the six focus groups indicated a current unwillingness to stop consuming titanium dioxide based on learning the substance is banned in the European Union. The exception was one individual in focus group 2 who indicated they would attempt to avoid exposing their children to titanium dioxide. Participants in all six focus groups, however, expressed the need for additional information and the desired nature of such information. Most saw a deficit in the quantity and quality of information available. Some questioned the motives of the FDA, and others saw the European Commission as credible despite their lack of familiarity with it. Respondents expressed a need for personal diligence in confirming or expanding on the information provided before deciding to stop consuming products with titanium dioxide.

DISCUSSION

Regarding the distinction between hazard and risk, the participants in this study appeared comfortable with the FDA restriction placed on the quantity of titanium dioxide present in food products. Although none of the participants denied that titanium dioxide could be hazardous, their focus appeared less on the hazard and much more on the risk posed to them as consumers. Participants consistently saw the risk as low. One exception was a parent showing concern for their children’s safety. This finding suggests that American consumers are conditioned to assess dangers in their food products, with a focus on risk rather than hazard. The focus on risk and risk tolerance fits with the assumption established by Barlow et al. (1) that food safety is not absolute. Although agencies such as the FDA attempt to identify and disallow or avoid hazardous ingredients and biological factors causing

adverse effects in the food supply, respondents seemed to accept that some degree of risk is always present.

The fact that many of the participants expressed an inability to discriminate among potential hazards in the food supply fits with the findings of Verbeke et al. (25). These findings suggest that consumers are somewhat overwhelmed by the number of potential food supply hazards brought to their attention by government agencies, nonprofit organizations, and media sources. Participants in this study articulated a similar perception of information overload and implied that titanium dioxide is simply another hazard about which they know little. Still, much of the discussion in the focus groups concentrated on the need for more information and the importance of personal responsibility where consumers seek out their own information. This finding reveals an informational paradox (19) (Fig. 1). Respondents said they were both overwhelmed or desensitized by the wealth of information about the many potential hazards they face and disappointed in the lack of information available, and they articulated the personal obligation or commitment to seeking out more information.

The information paradox observed in this study aligns with the recommendations provided by Littlefield et al. (11). Consumers appreciate and are more likely to comply with safety recommendations when hazards and risks are discussed interactively, allowing for feedback through dialogue. Individuals at risk want and need more information about (i) how to distinguish among hazards and (ii) how to make healthful choices. Sellnow et al. (18) recommended involving consumers in conversations about food safety by seeking feedback on content, soliciting and answering questions, and listening to consumer concerns—even when those concerns are not necessarily scientifically credible.

Simply adding more information in the form of additional regulations and explanations appears ineffective, based on the findings of this study. Participants in this study indicated that they would seek additional information from additional sources (including themselves and their peers) before they would alter their current behavior. As Littlefield et al. (11) suggested, government agencies and other organizations can and should participate in food safety discussions interactively.

Trust in science and government agencies emerged as a barrier to credibility for some participants. One person indicated an unwillingness to trust “anyone with a Ph.D.,” whereas others emphasized the potential biases and fiscal interests of agencies such as the FDA or European Commission. Although difficulties achieving compliance with food safety recommendations for food preparation in the home (3) and an increasingly globalized food trade system (2) are well documented, less is known about the extent to which lapses in compliance stem from a distrust in science and in risk communication practitioners. In the titanium dioxide case, the fact that two science-based agencies offered contrasting recommendations may have introduced, stimulated, or intensified frustration and related distrust in science. However, further research is needed to fully comprehend the source of such distrust and the impact it has on food safety decisions.

Limitations

We attempted to avoid selection bias by sharing recruitment duties with three members of the research team. However, we acknowledge that our need to use a convenience sample was a limitation. We also acknowledge that our reliance on self-identified gender as the only demographic variable is also a limitation.

Practitioner recommendations

From our results, we distilled several recommendations for risk communication practitioners, focusing on transparency in instructional information from industry to consumers and dialogue among national and international regulatory agencies and industry.

The participants in this study were largely unaware of the distinction between hazard and risk. Risk communication practitioners would likely benefit from explaining this distinction when seeking to reconcile opposing viewpoints from international agencies. Without knowledge of this distinction as a foundation, consumers may perceive the conflict as another reason to distrust or disregard safety recommendations.

Risk communication practitioners also would benefit from maintaining a transparent distinction between risk and crisis. Risk has been described in detail in this study; however, a crisis is a distinct communication event. Crises demand an urgent response, and lives may be in immediate danger (14, 23). For example, when an outbreak of Shiga toxin-producing *Escherichia coli* infections or illnesses caused by *Salmonella*

Newport or other deadly *Salmonella* strains occur among consumers, a rapidly distributed warning recommending specific and immediate actions is needed for self-protection (20). Given the difficulty comprehending various hazards that participants in this study expressed, an unequivocal and prompt warning about food crisis events should stand apart from other risk-related communications. If such warnings were greeted with the same indifference we saw regarding many messages generally focused on food hazards and risk, lives could be lost needlessly.

Much of the disagreement in food safety issues such as that regarding titanium dioxide stems from the broad use of the precautionary approach in the European regulatory framework. Application of the precautionary principle in food safety results in the ban or withdrawal of ingredients or products for which the European Community determines insufficient scientific evidence exists to establish the absence of dangerous effects (15). The expectations created through the precautionary principle can create a schism with countries outside Europe when determining what constitutes sufficient proof of safety. Thus, dialogue in the form of negotiation is needed to reconcile disagreements about what level of evidence constitutes sufficient proof of consumer safety (20). Thus, risk communication practitioners may also benefit from encouraging dialogue among governing agencies and other stakeholders where their concerns, questions, and irritations are heard and meaningful responses are provided. This process of assessing stakeholder positions is collaborative and interactive. Such an alliance is essential to advancing public understanding and promoting concepts in a way that achieves consensus. Through dialogue, risk communication practitioners position themselves as information providers, leading discussions among key stakeholders to affirm current thinking and to assess additional findings.

Dialogue of this nature could help reconcile conflicting perceptions of food safety related to the European Union's reliance on the precautionary principle for managing risk. Such dialogue could capitalize on the current high degree of coordination between the FDA and the EFSA. Existing alliances involving the Codex Alimentarius Commission, the Food and Agriculture Organization of the United Nations and the World Health Organization (FAO/WHO), and the Joint FAO/WHO Expert Committee on Food Additives could further advance the dialogue internationally. Continued and expanded dialogue among these agencies could enhance communication to consumers about conflicting interpretations of hazard and risk. Future research should explore the means for inspiring and coordinating such dialogue.

Titanium dioxide will not likely be the final disagreement between the FDA and European Commission. Hazard-based and risk-based assessments will continue to produce contradictory recommendations. This study revealed

how consumers reacted, in their own words, to such a contradiction. Ignoring the communication consequences of contrasting policies based on inherent differences between hazard and risk communication approaches could diminish trust in regulatory agencies specifically and scientific evidence in general. Failure to offer such clarity and interaction could result in risk communication practitioners simply providing more of the information that is ineffective or the source of the disconnection.

REFERENCES

- Barlow, S. M., A. R. Boobis, J. Bridges, A. Cockburn, W. Dekant, P. Hepburn, G. F. Houben, J. König, M. J. Nauta, J. Schuermans, and D. Bánáti. 2015. The role of hazard- and risk-based approaches in ensuring food safety. *Trends Food Sci. Technol.* 46:176–188.
- Boutillier, S., S. Fourmentin, and B. Laperche. 2021. History of titanium dioxide regulation as a food additive: a review. *Environ. Chem. Lett.* 20:1017–1033. <https://doi.org/10.1007/s10311-021-01360-2>.
- Byrd-Bredbenner, C., J. Berning, J. Martin-Biggers, and V. Quick. 2013. Food safety in home kitchens: a synthesis of the literature. *Int. J. Environ. Res. Public Health* 10:4060–4085.
- European Commission. 2022 Goodbye E171: the EU bans titanium dioxide as a food additive. Available at: <https://ec.europa.eu/newsroom/sante/items/732079/en>. Accessed 15 April 2024.
- European Food Safety Authority. 2021. Titanium dioxide: E171 no longer considered safe when used as food additive. Available at: <https://www.efsa.europa.eu/en/news/titanium-dioxide-e171-no-longer-considered-safe-when-used-food-additive#:~:text=After%20conducting%20a%20review%20of%20all%20the%20relevant,dioxide%20safe%20when%20used%20as%20a%20food%20additive>. Accessed 22 February 2022.
- Heil, E. 2022. Skittles lawsuit claims ‘toxin’ makes them ‘unfit for human consumption.’ *Washington Post*, 18 July. Available at: <https://www.washingtonpost.com/food/2022/07/18/skittles-lawsuit-toxin-titanium-dioxide/i>. Accessed 22 February 2024.
- Henson, S., and J. Caswell. 1999. Food safety regulation: an overview of contemporary issues. *Food Policy* 24:589–603.
- Kleter, G. A., and H. Marvin. 2009. Indicators of emerging hazards and risks to food safety. *Food Chem. Toxicol.* 47:1022–1039.
- Lammerding, A. M., and A. Fazil. 2000. Hazard identification and exposure assessment for microbial food safety risk assessment. *Int. J. Food Microbiol.* 58:147–157.
- Lincoln Y. S., and E. G. Guba. 1985. *Naturalist inquiry*. Sage, Thousand Oaks, CA.
- Littlefield, R. S., D. D. Sellnow, and T. L. Sellnow. 2021. Integrated marketing communications in risk and crisis communication contexts: a culture centered approach. Lexington Books, Lanham, MD.
- Miranda, S. 2022. A Skittles lawsuit raises questions over titanium dioxide—a legal food additive. National Public Radio. Available at: <https://www.npr.org/2022/07/22/1112929301/skittles-lawsuit-titanium-dioxide>. Accessed 10 April 2024.
- Omari, R., G. K. Frempong, and W. Arthur. 2018. Public perceptions and worry about food safety hazards and risks in Ghana. *Food Control* 93:76–82.
- Peachman, R. R. 2022. A lawsuit claims Skittles are unfit for consumption. Experts weigh in. *New York Times*, 26 July. Available at: <https://www.nytimes.com/2022/07/26/well/eat/skittles-lawsuit-titanium-dioxide.html?searchResultPosition=1>. Accessed 22 February 2024.
- Pettoello-Mantovani, C., and B. Olivieri. 2022. Food safety and public health within the frame of the EU legislation. *Glob. Pediatr.* 2:100020. <https://doi.org/10.1016/j.gpedts.2022.100020>.
- Powell, D. A. 2000. Food safety and the consumer—perils of poor risk communication. *Can. J. Anim. Sci.* 80:393–404.
- Sandman, P. M. 2003. Responding to community outrage: strategies for effective risk communication. American Industrial Hygiene Association, Fairfax, VA.
- Sellnow, D. D., D. R. Lane, T. L. Sellnow, and R. S. Littlefield. 2017. The IDEA model as a best practice for effective instructional risk and crisis communication. *Commun. Stud.* 68:552–567.
- Sellnow, T. L. 2024. Communicating science about controversial food ingredients. Presented at the meeting of the Food Ingredients Safety Committee, International Food Information Council, Washington, D.C., 15 February 2024.
- Sellnow, T. L., and D. D. Sellnow. 2024. Before crisis: the practice of effective risk communication. Cognella Academic Publishing, San Diego, CA.
- Singh, P. K., R. P. Singh, P. Singh, and R. L. Singh. 2019. Food hazards: physical, chemical, and biological, p. 15–65. In R. L. Singh and S. Mondal (ed.), *Food safety and human health*. Academic Press, San Diego, CA.
- Tracy, S. J. 2020. *Qualitative research methods: collecting evidence, crafting analysis, communicating impact*, 2nd ed. Wiley Blackwell, Hoboken, NJ.
- Ulmer, R. R., T. L. Sellnow, and M. W. Seeger. 2023. *Effective crisis communication: moving from crisis to opportunity*, 5th ed. Sage, Thousand Oaks, CA.
- U.S. Food and Drug Administration. 2024. Titanium dioxide as a color additive in foods. Available at: <https://www.fda.gov/industry/color-additives/titanium-dioxide-color-additive-foods>. Accessed 10 April 2024.
- Verbeke, W., L. J. Frewer, J. Scholderer, and H. F. De Brabander. 2007. Why consumers behave as they do with respect to food safety and risk information. *Anal. Chim. Acta* 586:2–7.
- World Health Organization. (n.d.). Food safety. Available at: https://www.who.int/health-topics/food-safety#tab=tab_1. Accessed 10 April 2024.
- Zoom. 2020. *Zoom meetings training—reference guide*. Available at: https://assets.zoom.us/docs/user-guides/Zoom-Meetings-Training-Reference-Guide.pdf?_ga=2.55015723.1252459791.1713985096-634719737.1713985096. Accessed 10 March 2024.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

No AI or AI-assisted technologies were used in any phase of this manuscript’s development and writing.