Public Perception of Nanoparticles in Food

An Interactive Qualifying Project

Worcester Polytechnic Institute

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Abstract

The goal of this project, sponsored by the Adolphe Merkle Institute, was to identify through surveys and interviews the Swiss public's opinion and level of knowledge about nanoparticles in food. Nanoparticles are particles on the nanoscale engineered and intentionally added to food to improve its properties. The results indicated that the public conflates nanoparticles intentionally added to food with microplastics. The recommendation was to emphasize in the media the distinction between intentional nanoparticles and polluting microplastics.

Acknowledgements

Our team would like to thank our sponsor Dr. Ana Milosevic, a researcher on BioNanomaterials at the Adolphe Merkle Institute (University of Fribourg), for all her help in guiding and shaping our project, as well as connecting us with others for interviews and surveys. We would not have been able to complete this project without her time and effort.

We would also like to thank Professor Dr. Barbara Rothen-Rutishauser, Dr. Sergio Bellucci, and Christine D'Anna-Huber for allowing us to interview them and for providing additional resources for our project. We appreciated Prof. Dr. Barbara Rothen-Rutishauser's efforts to assist Dr. Milosevic and us in sending out the surveys. We are grateful to the University of Fribourg for allowing us to send one of our surveys using their email list.

We are appreciative of all the individuals who responded to our surveys, and to those who we interviewed or who filled out our longform survey. We would not have been able to complete this project without the thier responses.

Our project also would not have been the same without the help and work that Ralph Perry Jr. did on our project proposal. We would like to thank him for his efforts drafting and writing the proposal.

We finally would like to thank our advisors Professor Ulrike Brisson and Professor Blake Currier from Worcester Polytechnic Institute who provided guidance and extensive feedback on our project.

Executive Summary

Nanotechnology has greatly developed over the last twenty years. Nanoparticles are defined as any particle of a material with at least one dimension in the 1nm to 100nm range (Buzby, 2010, p. 528) that retains the original material's properties on that scale (Hardy *et al.*, 2018, p. 3). Nanoparticles are currently used in food in many ways, including: as a colorant, to add nutritional value, and to increase the shelf life of a product (Chen & Wagner, 2004, p. 1432). Although there are naturally occurring nanoparticles (Hardy *et al.*, 2018, p. 3), those that are intentionally added to foods are the focus of this project. With each nanoparticle used, an assessment of the risks must be performed (Hardy *et al.*, 2018, p. 15). This assessment has already been completed for all nanoparticles currently used in food products, and the nanoparticles studied have been deemed safe at reasonable concentrations.

Despite their wide usage, the public seems to be largely unaware of nanoparticles. The goal of this project was to understand the Swiss public's current opinion and knowledge of nanotechnology used in foods. This goal was achieved through the following objectives:

1. Determine the current media accessible to the Swiss public on nanoparticles in food.
2. Determine the current knowledge and opinions held by a sample of the public on nanoparticles in food.
3. Evaluate how representative the surveyed population is in relation to the entire Swiss public.
4. Determine the information the public needs to achieve an informed understanding of nanotechnology in food.
5. Identify resources necessary for the public to gain an informed understanding of nanoparticles in food.

Objective 1

To determine current media accessible to the public on nanoparticles in food, we performed a content analysis. We reviewed a variety of Swiss published media, including newspapers, advertisements, and magazines. This content analysis allowed us to gain a general idea of how nanoparticles are reported on in the Swiss general media (Ryan & Wiesner, 1998).

After completing the content analysis we found that most media published about nanoparticles is not written in layman's terms and are therefore less accessible to the general

public. We also found that microplastics had a larger media presence than nanoparticles, and only a few articles described nanoparticles intentionally added to food.

Objective 2

To determine the current knowledge and opinions held by a sample of the public on nanoparticles in food, we carried out two surveys and an interview.

The results of the initial survey showed that a large percentage of the respondents associate nanoparticles in food with microplastics or other material residue, and around 15% of respondents knew little or nothing about nanoparticles in food. In addition the connotation/tone of most of the responses were either neutral or negative. This indicates that currently the public does not see nanoparticles in food as a beneficial technology. Moreover, many of the responses discussed unintentionally added nanoparticles or microplastics and did not address intentionally added nanoparticles. This probably means that the respondents to the initial survey do not know much, if anything, about nanoparticles intentionally added to food.

The second survey, which was sent to an email list of individuals with a higher level of education than the first survey, asked participants to check off topics that they associate with nanoparticles in food from a given list; **Figure i** shows the total tallies for this survey question. More participants included a list of specific additives than in the initial survey. A similarity between the surveys is that microplastics were commonly checked off or listed.

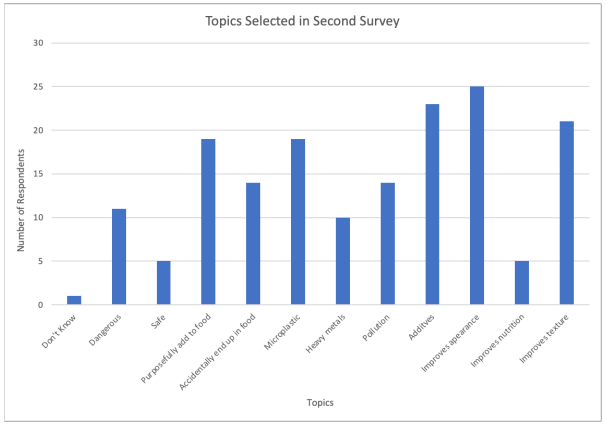

Figure i: *Second survey: Selected topics associated with nanoparticles in food.*

The second survey also asked participants to rate their opinion of nanoparticles intentionally added into food (**Figure ii**) and to rate their opinion of microplastics (**Figure iii**). Because microplastics and nanoparticles in food are commonly confused by the public the overall opinion of nanoparticles in food is probably more negative than if the two particles were not conflated by the public.

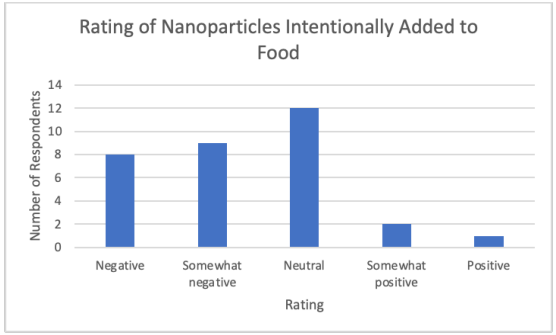

Figure ii: *Second survey: Participants' rating of nanoparticles intentionally added to food.*

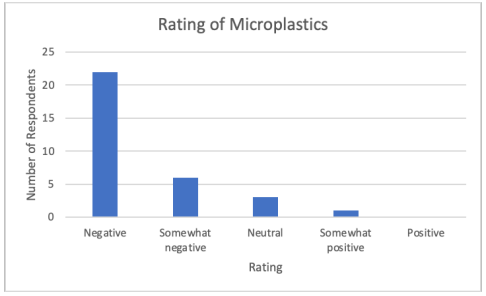

Figure iii: *Second survey: Participants' rating of microplastics.*

Our final method employed in this objective was a longform survey/interview. Even though all the participants had heard of nanoparticles, most respondents were unable to describe how nanoparticles are used in food. Moreover when participants were asked "Have you ever heard of microplastics and what do you know about it?" all participants were able to describe where microplastics are found or how they are formed.

Combining all of the results of the surveys and interviews, it is evident that the public knows little about the difference between intentionally added nanoparticles and unintentionally added particles, which results in confusion between intentionally added nanoparticles and microplastics. This confusion then leads to the public having a more negative opinion of nanoparticles present in food products. From the surveys and the interview we can see that the public makes little distinction between nanoparticles and microplastics; the latter being what the public focuses on.

Objective 3

The results were then evaluated to see how representative that small sample population is of the entire Swiss public. The surveys included demographic questions on age, education, and whether the participant's work or study involved nanotechnology. The answers of these questions were compared to demographic information of the Swiss population.

The majority of the respondents to the initial and second surveys were 54 or younger. No respondents were over the age of 65, even though individuals 65 and over make up 17.8% of the

population (Federal Statistics Office, 2015). However the ages represented in the surveys are fairly representative of the consumer market.

The education of the respondents to the initial and second survey were very different. Most of the participants of the initial survey had only a secondary school education or Bachelor's degree, while most of the participants in the second survey had at least a Master's degree. Both survey populations probably contain more academics than the general Swiss population, because the surveys were primarily carried out at the University of Fribourg.

The vast majority of the initial survey respondents' work or study did not involve nanotechnology, while the majority of respondents to the second survey work or study did. Interestingly, confusion between intentionally and unintentionally added nanoparticles is even prevalent among those who study nanotechnology, as well as the confusion of intentionally added nanoparticles and microplastics.

For all the demographics from the initial survey, the two highest topics listed were material residue and safety/health, and the connotation of the responses was more negative than positive.

Overall it was determined that the sampled population is not representative of the entire Swiss population but provides reasonable insight on the knowledge and opinions of Swiss public ages 55 and under.

Objective 4

To determine the information the public needs to achieve an informed understanding of nanotechnology in food, we interviewed a nanoparticle expert, Dr. Barbara Rothen-Rutishauser. We conducted a semi-structured interview with her to answer questions such as "What information do you feel is important for the public to know about nanoparticles?"

Through this interview we learned that the following is necessary for the public to be informed about nanoparticles in food: what nanoparticles are, their properties, size, and why they are added to consumer products. This information would help define nanoparticles to the public and increase the distinction between them and microplastics.

Objective 5

We identified resources necessary for the public to gain an informed understanding of nanoparticles in food through conducting a semi-structured interview with a communications

expert, Christine D'Anna Huber. The results of this interview and the second survey were used in writing the recommendations of this project.

Altogether, we concluded that the public has limited knowledge of nanoparticles in food and confuses nanoparticles in food with microplastics. To rectify this confusion we recommend that the Adolphe Merkle Institute should work with communication experts to design media for the general public, which will emphasize the distinction between nanoparticles that are specifically engineered and added into food to create more appealing traits, and microplastics that are plastic residue that ends up on or in food products. From the second survey and the interview with Christine D'Anna Huber, we learned that the most requested and recommended platforms are public radio, newspapers, and websites. As suggested in conversation with our sponsor Dr. Ana Milosevic, a workshop for science journalists is also recommended as an initial step in spreading information on the use of nanoparticles in food products.

After these recommendations are carried out, the public opinion of nanoparticles in food in Switzerland should be reassessed. We recommended that this should be completed through an improved survey. This survey population should include individuals from all of the Swiss cantons and adults of all ages. This survey should also be given in all four official languages of Switzerland to ensure accessibility to the general population.

These recommendations should allow the institute to clarify the distinction between nanoparticles in food and microplastics, and to outline a method to test whether this clarification has resulted in change in public's opinion and level of knowledge of nanoparticles. For the continuing and increased use of nanotechnology, the public needs to have access to information on nanoparticles that are specifically added into food products, and research projects must be continually conducted to assess and ensure the safety of these foods.

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Authorship

Ralph Perry Jr., Rayna Harter, and Marika Bogdanovich all contributed to the research and writing of this project. The final project was written and executed by Rayna Harter and Marika Bogdanovich. An in depth division of work is as follows:

Ralph Perry contributed greatly to the initial project proposal. He contributed to the Introduction, Background Topic 4, and Appendix B.

Rayna Harter was responsible for the Abstract, Acknowledgements, Background Topics 2 and 4, Methods Objectives 2 and 3, Results and Discussion Points 2 and 3, and Appendices A, B, C, and H.

Marika Bogdanovich was responsible for the Introduction, Background Topics 1, 3, and 5, Methods Objectives 1, 4, and 5, Results and Discussion Points 1, 4, and 5, and Appendices D, E, F and G.

Rayna Harter and Marika Bogdanovich contributed equally to the Executive Summary and Conclusion and Recommendations of this report. Both continually made edits to the grammar, the content, and the flow of this project.

1. Introduction

Improving the quality of the food a society produces has been a priority since the beginning of agriculture. Current technology enables us to manipulate food on the microscopic scale. Genetic modifications, for example, allow for more diverse advancements to be made. Genetic modifications are responsible for improvements such as increasing the amount of Vitamin A in rice (Anderson, Jackson, & Nielsen, 2005, p. 773) or making canola crops resistant to herbicide (Rieger, Lamond, Preston, Powles, Roush, 2002, p. 2387).

Much like genetically modifying foods, nanoparticles exist in foods naturally, in forms such as proteins and lipids. Currently, the technology exists to implement other materials of nanoparticle size, such as titanium dioxide and silicon dioxide, to improve our food. Nanoparticles, for example, can be used as a colorant, or to add nutritional value, or to increase the shelf life of a product.

Despite their wide usage, the public seems to be largely unaware of nanoparticles. Recent studies in the U.S. and Europe have shown that the public accepts nanoparticles (Burgess, Cuite, Hallman, Kuang, & Tepper, 2020, p. 8) when informed of the uses and benefits nanoparticles provide. During their study the uses and benefits were explained to participants before their opinion was recorded. This may have skewed the data because in another study that was carried out by Eyck, Gaskell, Jackson, and Veltri, the participants were not informed, and many participants responded that they did not feel informed enough on nanoparticles to give a meaningful answer (2005).

The goal of our project was to understand the Swiss public's current opinion and knowledge of nanotechnology as used in foods. We achieved this goal through the following objectives and associated methods:

1. Determine the current media accessible to the Swiss public on nanoparticles in food.

This objective was accomplished through a content analysis focused around media published in Switzerland on nanoparticles in food. We considered the questions "What attitude is being conveyed?" and "What information is presented and where is it available?" when assessing the media.

2. Determine the current knowledge and opinions held by a sample of the public on nanoparticles in food.

We achieved this objective largely through surveying the public. The surveys were sent out either through the mailing list of the University of Fribourg or the Adolphe Merkle Institute, and forwarded to the recipients' associates. We hoped to answer the questions: "How much do the individuals sampled know about nanoparticles in food?" and "What is their overall opinion of nanoparticles in food?"

3. Evaluate how representative the surveyed population is in relation to the entire Swiss public.

In the survey participants were asked to give their demographic information. This information was compared against Swiss demographics to assess its accuracy in representation.

4. Determine the information the public needs to achieve an informed understanding of nanotechnology in food.

This objective was reached through an interview with a nanoparticle expert, Dr. Barbara Rothen-Rutishauser. Some of the questions we asked her included: "What information do you feel is important for the public to know about nanoparticles?", "What is your opinion on the current policies surrounding nanoparticles?", and "What research on nanoparticles is currently being conducted that you are aware of?" This provided us with a base for the information the public should know.

5. Identify resources necessary for the public to gain an informed understanding of nanoparticles in food.

For this objective, we interviewed communications expert Christine D'Anna Huber to gain insight on the forms of media commonly used by the Swiss public. The results from this interview were used in creating recommendations for increasing the Swiss public's access to information about nanoparticles in food.

2. Background

In the last twenty years nanoparticles have been added to food products, and researchers have studied the risks, benefits, and public opinion of this technology. In the following sections, we:

1. Define nanoparticles.
2. Provide a description of few specific applications of engineered nanoparticles in the food industry.
3. Explain the current legislation in the European Union (EU) and in Switzerland on the use of nanoparticles in food.
4. Describe past public opinion research on nanoparticles in food.

2.1 What Are Nanoparticles?

As their name indicates, nanoparticles are particles with a length of 1 to 100 nm in at least one dimension (Buzby, 2010, p. 528) that retain the properties of the material on the nanoscale (Hardy *et al.*, 2018, p. 3). For perspective, the size difference between a one-inch marble and the Earth is comparable to the difference between a nanometer and a meter (Rhodes, 2014, p.173). Much is known about naturally occurring nanoparticles, such as proteins, carbohydrates, and lipids (Hardy *et al.*, 2018, p. 3). Nanoparticles that are intentionally created or engineered have been developed in the last few decades; there is still much that can be learned about these. Nanoparticles are extremely diverse and their use must be designed and evaluated independently (Fabricius, Goetz, Hristovski, Westerhoff, & Weir, 2012).

2.2 Applications

The addition of nanoparticles to food can result in a variety of benefits in the health, sensory, and safety areas (Rhodes, 2014, p. 178). Nanoparticle technology has the potential to increase shelf life, nutrition, and overall appeal of foods. Every specific nanoparticle is structurally and chemically different; as a result, they must be evaluated individually for risks and benefits (Buzby, 2010, p. 530). Since it is impossible to make generalizations about all

nanoparticles, this section will outline how a few specific nanoparticles and how they are used to improve products.

2.2.1 Increased Nutritional Value

Some nanoparticles are used to increase the nutritional value of food. For example reducing the size of vital nutrients can allow more to be added without adversely affecting a food. This can be accomplished with high-pressure homogenization or other methods. High-pressure homogenization is when a liquid mixture is "forced at high pressure through a narrow valve [,]" which results in tiny mixture droplets. These are then added directly into food products or beverages (Chen & Wagner, 2004, p. 1435). This technique is used to produce Vitamin E nanoparticles to be used in beverage applications (p. 1436). Vitamin E is an antioxidant and essential nutrient that can be beneficial to the immune system and the health of skin and hair. Some individuals lack Vitamin E due to irregularities in their dietary fat absorption or metabolism; supplementing beverages with Vitamin E nanoparticles can combat these deficiencies (p. 1432). Although Vitamin E at extremely high doses ("the upper limit for adults is 1,100 mg/day for supplements[;]" for reference, the recommended daily intake for adults is 15mg) can result in bleeding in the brain or increased bleeding from an injury (Office of Dietary Supplements, 2020), but the amount of Vitamin E in fortified foods and beverages is so small the likelihood of adverse effects is minimal.

Vitamin E nanoparticles are not the only nanoparticle that can be added into food to improve properties. Other antioxidants, such as gamma oryzanol, can be used to limit the effect of nutrient degradation. Oxidation begins to break down the nutrients in food as soon as it is exposed to air (Ghaderi, Ghanbarzadeh, Mohammadhassani, & Hamushehkar, 2014, p. 550). One way to combat this natural process is by adding antioxidants. These antioxidant nanoparticles are encapsulated with a biocompatible polymer, producing a controlled release of the antioxidant into the food, leading to more nutritious food overall (p. 549).

2.2.2 Increased Visual Appeal

In many cases, increasing the nutritional value of a product will cause the product to be less visually appealing. For both Vitamin E and other antioxidants, this decline in the visual aspect can be avoided by using these additives in a nanoparticle form. This allows producers to create appealing products meeting the demands of consumers (Bishai & Nalubola, p. 46).

Fortification with conventional Vitamin E additives result in less appealing characteristics in beverages. These issues can be resolved by using Vitamin E in nanoparticle form to fortify the beverages. Conventional Vitamin E additives come in two forms; solid and liquid. When added to beverages, conventional solid Vitamin E additives make the beverages appear cloudy. Additionally, conventional Vitamin E additives are not very stable in beverages and will congeal at the top of the beverage after a few days, producing an unappealing film. One study found that Vitamin E nanoparticles, when used as a beverage additive, resulted in both improved clarity and stability of the product (Chen & Wagner, 2004, p. 1432).

When antioxidants are used to decrease nutrient degradation, the nanoparticles are encapsulated with a biocompatible polymer. Without this nanoencapsulation technology, the antioxidant gamma oryzanol, when added to a beverage, would change the beverage's appearance because gamma oryzanol is insoluble in water (Ghaderi, Ghanbarzadeh, Mohammadhassani, & Hamushehkar, 2014, p. 550). One study found that when gamma oryzanol is encapsulated within a biocompatible polymer, there was no change in the quality of the antioxidant function and it did not affect the clarity or viscosity of a liquid food product. Additionally, the study found that the gamma oryzanol nanoparticles were stable for at least five weeks (p. 553).

Nanoparticle applications are not limited to nutrient applications; nanoparticle-sized additives can improve the quality of food in other ways. Titania (TiO_2 or titanium dioxide) is a common nanoparticle added as a white colorant to candy, sweets, and gum. This addition makes a food product more visually appealing and enjoyable to the consumer. Silica (SiO_2 or silicon dioxide) is another nanoparticle commonly added to food. Silica nanoparticles are used to prevent caking in powdered products or to improve the flow in viscous products (Spuch-Calvar, Caldwell, Geers, Rothen-Rutishauser, & Fink, 2019, p. 2). Both titania and silica are commonly used, but are not natural components of food. They both improve the appearance of a food product.

2.2.3 Improved Shelf-Life

Vitamin E nanoparticles in the beverage industry outperforms conventional additives in shelf life. In conventionally fortified beverages, the Vitamin E additive and the rest of the beverage separate, resulting in a film at the top of the beverage. The conventional approach to solving this issue is adding large amounts of surfactant (a substance that reduces surface

tension). The issue with this solution is that even when the regulatory limit of surfactant is reached, the Vitamin E concentration in the beverage itself is insignificant (Chen & Wagner, 2004, 1432). Nanoparticles offer another solution. When Vitamin E nanoparticles are added to a beverage instead of the conventional (non-nanoparticle) additives, the beverage does not separate even with higher concentrations of Vitamin E, even without surfactant. One study found that apple juice fortified with Vitamin E nanoparticles instead of the conventional additives could be stored for six months with minimal effects on the appearance (p. 1436).

Every specific nanoparticle is unique, but nanoparticles in general have many beneficial applications. Even though the addition of nanoparticles into food is promising, the public is concerned with the possible health and environmental effects they could potentially have.

2.3 Potential Risk and Concerns Associated with Nanoparticles in Food

The risks that have been found and investigated are associated mostly with inhalation during processing of the nanoparticles (Czajka *et al.*, 2015), meaning breathing in nanoparticles is the only intake method found to have a noticeable and concerning effect. This is due to the concentration of nanoparticles being significantly higher in these inhalation cases than in the consumption of consumer products. Although there is still much research to be done, there is currently little evidence to suggest that nanoparticles in food products will cause harm to consumers.

According to a risk assessment of titanium dioxide from 2016, TiO_2 nanoparticles pose a negligible risk to consumers (Heringa *et al.,* 2016, p. 1524). Research was done via two approaches: external intake and internal accumulation. External intake is based on dose and internal accumulation is based on concentrations in organs. Although the second approach resulted in a larger and more negative reaction, the study concludes that more research should be performed. At this time there is nothing that suggests titanium dioxide nanoparticles are a health concern, even in the long term.

A study on silicon dioxide nanoparticles concluded that they offer minimal risks to human microvilli (Yang *et al.*, 2016, p. 910). Microvilli are found on many cells, most commonly in the small intestine; they aid the body in absorbing nutrients (Robb, 2020). When damaged, microvilli are unable to absorb nutrients properly, which can lead to malnutrition. This

risk assessment also concluded that more research needs to be conducted to gain a complete understanding of the risk of the use of silicon dioxide nanoparticles.

As more research has been conducted, new information has been revealed. For example, it was previously thought that nanoparticle "size was [...] a large factor in toxicity, with smaller particles tending to be more toxic," but now it is believed that size is "only a single (and perhaps minor) factor influencing the toxicity of nanoparticles" (Weir, Westerhoff, Fabricius, Hristovski, & von Goetz, 2012, p. 2243). These risks and scientists' ever-evolving understanding of nanoparticles are sources of concern for the public. Thus, clear and open communication between the public and scientists is key for the continued use of nanoparticles in food products, as well as funding of research into their applications. Keeping consumers safe and educated on the effects of nanoparticles in their food is the responsibility of the government, academia, and food industry (Schmid & Riediker, 2008).

2.4 Switzerland Rules and Regulations on Labeling and Assessment of Possible Risks

Nanoparticles are already widely used in the food industry and current research has found them to be safe, but each nanoparticle needs to be evaluated separately. Research is continually being conducted to access the safety of new engineered nanoparticles present in food. Due to the inherent newness and possible risks of nanotechnology, legislation is necessary to protect and to inform the public. The European Union and Switzerland have implemented legislation specific to nanoparticles, defining a nanoparticle or nanomaterial as "a natural, incidental or manufactured material containing particles, [... where] 50% or more of the particles [... in the material, has] one or more external dimensions in the size range 1–100 nm" (Marrani, 2013, p. 187). Using this legal definition, both the European Union and the Swiss government have required labeling of the nanoparticle ingredients in products as "nano" (Federal Office of Public Health, 2018). The European Union requires that the word "nano" in brackets must be added after an ingredient if it is a nanoparticle (Baran, 2016, p. 52). For example, a gum containing TiO_2 nanoparticles would list "TiO_2 [nano]" in the ingredients. Besides labeling nanoparticle ingredients in food, Swiss legislation mandates that an assessment of the possible risks is performed on any new nanomaterial. All new nanoparticles must be licensed and evaluated by the Federal Food Safety and Veterinary Office (FSVO) (Federal Office of Public Health, 2018).

2.5 Public Opinion

One of the primary goals of nanoparticle related legislation is to inform the public about what they are eating and to ensure public safety. Therefore, it is important that the public has access to the knowledge on what nanoparticles are, what their benefits are, and what the current legislation is, so they can make an informed decision. Over the past decade, Switzerland's Federal Office of Public Health (FOPH) has funded research focusing on the potential health and environmental risks presented by nanoparticles. In the past few years, efforts have been made to make research more accessible to the public. Despite this effort to further public knowledge, it seems that much of the research is still not known by the general public.

2.4.1 Past Research on Perception

The general public seems to be accepting nanoparticles in food, but there is still concern about their inclusion in food products due to the incomplete knowledge about the long-term effects (Belli, 2012). This concern is very dependent on location and knowledge of an individual (Eyck, Gaskell, Jackson, & Veltri, 2005). **Figure 1** shows the results of the polls performed in the United States and in Europe.

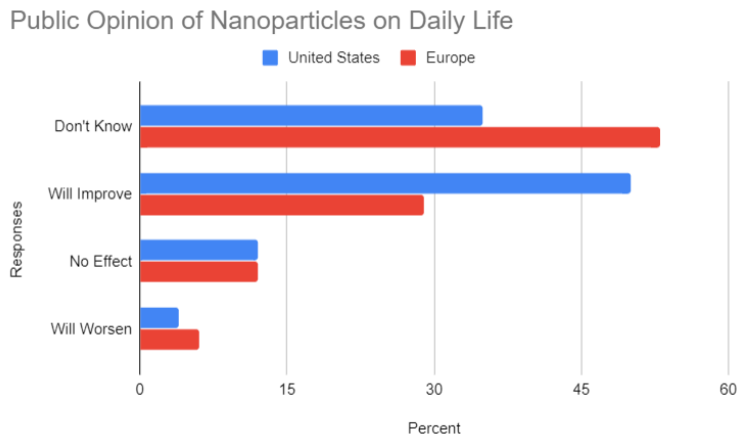

Figure 1: *Graph of poll results from data in Eyck, Gaskell, Jackson, & Veltri, (2005).*

Although Switzerland is the focus of our project, the opinion of the Swiss may have changed since 2005. Participants were asked if they thought nanoparticles could improve their daily lives. As seen in the figure, the most common responses were “yes, it will improve” and “don’t know,” with nearly opposite results in the US as in Europe.

Despite their lack of knowledge, U.S. consumers are willing to purchase products that are described as containing nanoparticles (Burgess, Cuite, Hallman, Kuang, & Tepper, 2020). The study presented different samples of chocolate ice cream and cherry tomatoes to participants who said they enjoy those products. When given the samples, the participants were told they included nanoparticles even though they did not. They were informed of the benefits the nanoparticles purportedly provided and were asked to rank their enjoyment of the product. At the end, participants were asked a number of questions, one of which addressed their willingness to purchase food products enhanced by nanoparticles. Less than 20% of participants answered that they would be unwilling to purchase those products. The reasoning of those who were unwilling was “not in objection to the technology; instead, they quite literally expressed their distaste for the products they believed to be produced with nanomaterials” (Burgess, Cuite, Hallman, Kuang, & Tepper, 2020).

In this study, participants were falsely informed about the presence of nanoparticles; therefore their opinions were purely “based upon their perceived nanotechnology benefits” (Burgess, Cuite, Hallman, Kuang, & Tepper, 2020) and do not reflect on any sensory ability to detect nanoparticles. The fact that a significant portion of participants were willing to purchase products that they thought used nanoparticles is indicative that informing consumers of the benefits and usages of nanoparticles will most likely lead to greater acceptance and understanding.

2.4.2 Common Confusion

When asking the public about nanoparticles, there is much confusion between intentionally added nanoparticles and unintentionally present packaging byproducts and environmental pollutants such as microplastics. Microplastics are pieces of plastics “less than five millimeters in length (or about the size of a sesame seed)” (National Oceanic and Atmospheric Administration). Microplastic particles are largely the result of plastic pollution in bodies of water (Cox, Covernton, Davies, Dower, Juanes, & Dudas, 2019). The plastic waste breaks down over time and contaminates the water. This causes environmental problems with

organisms on the microscale. These organisms mistake the plastic particles for food and ingest them, causing microplastics to contaminate organisms throughout the food chain (Guzzetti, Sureda, Tejada, & Faggio, 2018). Although the pollution from these microplastics are a concern, the media on microplastics may be framed more severely than what research supports (Völker, Kramm, & Wagner, 2019).

The current stigma surrounding nanoparticles is largely based on lack of information and the confusion with microplastics. This causes consumers to be wary of new products in spite of their improvements (Roosen, Bieberstein, Marette, Blanchemanche, & Vandermoere, 2011).

3. Methods Section

The goal of this project was to understand the Swiss public's current opinion and knowledge of nanotechnology used in foods. We achieved this goal through the following objectives:

1. Determine the current media accessible to the Swiss public on nanoparticles in food.
2. Determine the current knowledge and opinions held by a sample of the public on nanoparticles in food.
3. Evaluate how representative the surveyed population is in relation to the entire Swiss public.
4. Determine the information the public needs to achieve an informed understanding of nanotechnology in food.
5. Identify resources necessary for the public to gain an informed understanding of nanoparticles in food.

3.1 Determine the Current Media Accessible to the Swiss Public on Nanoparticles in Food

The current exposure the Swiss public has to nanoparticles was assessed through considering the questions "What attitude is being conveyed?" and "What information is presented and where is it available?" Using this information, we addressed the claims made in the media while providing a source of information for the public. This method is limited by the available media on the subject of nanoparticles. To accomplish this goal, we performed a content analysis. This involved investigating the information distributed about nanoparticles by television, radio, social media, newspaper, and other relevant forms of communication. This content analysis allowed us to gain a general idea of how the Swiss public are told to view nanoparticles (Ryan & Wiesner, 1998).

3.2 Determine the Current Knowledge and Opinions Held by a Sample of the Public on Nanoparticles in Food

To determine the current public opinion and knowledge of nanoparticles, we evaluated a sample of the general public using the University of Fribourg's email list and the associates of

the Adolphe Merkle Institute. We hoped to answer the questions: "How much does the sample know about nanoparticles in food?" and "What is the samples' overall opinion of nanoparticles in food?" The methods described below were used to answer these research questions.

3.2.1 Freelisting Survey

We used a freelisting survey to answer these research questions. This email survey included some general background questions (**Appendix A**) and one question that asked participants to freelist: "Would you please list all of the things that you can think of when you hear 'nanoparticles in food'?" The survey was sent out in English, German, and French and also included a few demographic questions.

The data we collected from background research was older and may not reflect the current opinion, therefore we selected freelisting, which is typically used when little is known about a research topic (Flinn, 1998, p. 86-87). Freelisting allowed us to complete more general exploration before designing specific questions for further surveys or interviews. The freelisting survey allowed us to gain a basic understanding of the associations that the sample population currently has on nanoparticles.

We analyzed the data from the survey's freelist question by sorting the items listed in the responses into broad categories. We used a preliminary analysis of the responses to determine the exact categories which responses were sorted into. The categories we used were: material residue, safety/health, environment, foods/additives, unknown (meaning the participant responded that they knew little or nothing about nanoparticles in food), and applications. Additionally, each response to the freelisting question was also evaluated based on overall tone and categorized as positive, positive-neutral, neutral, negative-neutral, or negative. These categories were then compared graphically to determine the things our sample thinks of most when they hear "nanoparticles in food" and the most common tone taken in the responses.

3.2.2 Second, More Refined Public Opinion Survey

A second, more refined, short public opinion survey was sent out after the analysis of the freelisting survey. This second survey continued to answer the research questions and was sent out to the associates of the Adolphe Merkle Institute, and individuals were asked to forward the survey to others that they knew. The survey asked the participants similar demographic questions as in the freelisting survey, and the project-specific questions in it were determined based on the freelisting survey responses. This survey asked participants:

1. To check off topics that they associate with nanoparticles in food from a given list,
2. To rate their opinion of nanoparticles intentionally added into food, and
3. To rate their opinion of microplastics (**Appendix B)**.

As was the freelisting survey, this survey was sent out in English, French, and German and should have taken participants 5 minutes or less to fill out.

We analyzed the responses to this second survey by graphing the results of each question. We also graphically compared the responses from this survey to the responses from the freelisting survey to determine if they were significantly different. When we compared the results of the freelisting survey and the second survey, we specifically compared the topics listed (freelisting survey) or checked off (second survey), and the connotation of the response (freelisting) or opinion of nanoparticles (second). The goal was to determine if the more structured response format of the second survey affected the responses.

One of the limitations of this second survey is that the survey population may include individuals already surveyed. Also the survey was only sent out to the Adolphe Merkle Institute, which is a more specialized group than the University of Fribourg, and participants were asked to forward the survey on to others they knew. This means that differences in responses could be due to a different survey population, the different questions, or the less diverse survey population.

3.2.3 Interviews and Longform Surveys with Swiss Public

After the initial survey responses were received, we asked individuals to participate in an interview to provide further insight into the responses received previously. Due to some conflicts, such as scheduling and language, a longform survey was developed and sent to the individuals. One interview was performed and we received three responses to the longform survey. The results from the freelist were used to determine the exact interview/survey questions. The questions included: “Have you ever heard of nanoparticles?” and “Do you know what they are used for?” (The expanded list of questions is included in **Appendix C**.) If the participant did not know what nanoparticles were, we provided some general background information for the interview; this was impossible for the longform surveys. Only one of the freelisting survey participants was comfortable being interviewed in English. This interview expanded our general understanding of the Swiss public’s opinion of nanoparticles in food.

The interview was a half-hour-long online interview via Zoom that was audio-recorded and conducted in a semi-structured format. The semi-structured interview format allowed for

additional questions to be asked based upon what was said by the participant. Additionally, when anything unexpected was brought up during the interview, this format allowed us to adapt and ask further questions to avoid missing key details (Berg & Lune, 2012, p. 113). A thirty-minute interview provided enough time to connect and understand the individual's opinion of the use of nanoparticles in food.

Since only one person was confident enough to be interviewed in English, the longform survey questions were sent out to the other individuals who said in the freelisting survey that they would like to be contacted further. The interview questions were sent out in English and the responses were analyzed in the same manner as the Zoom interviews. One of the limitations of this technique is that we could not further clarify the questions and provide the needed background information which might arise spontaneously.

3.2.4 Data Analysis of Interviews and Longform Surveys

The data collected through the interviews/longform survey were analyzed using the qualitative analysis techniques outlined by Beebe (2014) in *Rapid Qualitative Inquiry* (pp. 85-93). We began analyzing data while interviews were still being conducted. All of the interviews were recorded and transcribed, and the transcriptions were coded and additional remarks were added in margins. These remarks were used to note reactions or comments that are important, but do not fit into one of the particular codes listed above. Once the transcriptions were created, they were annotated to help organize the information received. This process helped condense the data. We looked at the data to determine associations and groups; then, we generated meaning from those groups of data. We then compared the data we obtained from the interviews and the surveys to evaluate consistency and to reach a conclusion.

3.3 Evaluate How Representative the Surveyed Population is in Relation to the Entire Swiss Public

To extend the findings from our surveys and to apply them to the entire Swiss population, we first determined whether our sample population was representative of the Swiss population. We completed this objective by answering the following research questions: “How does the sample compare the general Swiss population?” and “To what extent is the sample population representative of the entire Swiss population?”

To answer these research questions we used the demographic data from the surveys on age, education, and field of work or study. We considered whether the difference in demographics affected the participants' opinion of nanoparticles to determine how skewed the responses were and whether the conclusions could be extended to include the entire Swiss population. The initial surveys were sent out to a university population, and then we asked participants to forward along the survey to others they knew. This resulted in the majority of our participants being individuals who are undergraduate students, graduate students, and professors, but some of the population will include employees of the university working in admissions, food preparation, or other non academic areas. Additionally, since these surveys were sent out through a university emailing list, some of the respondents could be international students and are not a part of the Swiss public. Another limitation to these surveys is that the participants surveyed were younger than average for the Swiss public and a large percent are working or studying in academia. One method that was used to provide a better representation of Switzerland was that the survey was sent out in English, German, and French. This allowed the survey to be more accessible to the Swiss population, since German and French are two of the official written languages in Switzerland and English is not.

The results of the freelisting survey were also compared graphically by age, education, and whether their work or study involves nanotechnology. The second public opinion survey had corresponding demographic questions, but results of non demographic questions were not compared by demographic since a sample of 25 is too small to obtain reliable results.The open-ended demographic questions from the freelist survey were also sorted into categories to allow for comparisons. The education level achieved in each response was sorted into the following categories: secondary school, bachelors, masters, or PhD/MD. The field of study responses were also categorized in the following groups: technology (science, engineering, math, computer science), social science, law, health/medical, administration/business, community/social services, education, and other.

Additionally, a statistical comparison of the overall tone of the responses from the freelist survey was compared to the participants' demographics to determine whether there was a link between the demographics and their overall tone of response. If age, education, and/or whether a person's field of work or study involved nanotechnology were linked to the tone/connotation of the response was evaluated using Fisher's exact test. The alpha value for the test was set to .05

and the null hypothesis was that the demographic being tested was independent of the connotation of the freelist responses. The alternative hypothesis is that the demographics and connotation are linked. Fisher's exact test was chosen because it can be used to determine whether two types of categorical data are linked. Fisher's exact test was chosen over Chi-square test for independence, which tests for correlational independence, because our sample size was small and the calculated theoretical counts were less than 5. In this situation, the Chi-square test is not appropriate to use.

3.4 Determine the Information the Public Needs to Achieve an Informed Understanding of Nanotechnology in Food

Through our background research we have established an understanding of nanotechnology in food. We must now condense this information and determine what is crucial for an informed understanding of nanotechnology in food as well as resources the public can access to increase their understanding. To achieve this objective we had to answer: "What resources are available to the Swiss public?" and "How much background information is necessary to achieve an informed understanding of nanoparticles in food?"

To answer these questions, we used the information collected during the literature review portion of the project and the semi-structured interviews with a nanoparticle expert, Barbara Rothen-Rutishauser. Barbara Rothen-Rutishauser works in the bio-nanomaterials field and holds positions as a professor and lead researcher at the Adolphe Merkle Institute in Fribourg, Switzerland. We conducted this 30-minute semi-structured interview remotely through an audio-recorded Zoom session. Some of the questions asked included: "What information do you feel is important for the public to know about nanoparticles?", "What is your opinion on the current policies surrounding nanoparticles?", and "What research on nanoparticles is currently being conducted that you are aware of?" A full list of questions can be found in **Appendix C**. The interview was analyzed using the same process described in the second objective (section *3.2.4*). This interview was used to determine what experts think of the use of nanoparticles in food and what they feel is essential for the public's understanding of nanoparticles in food. We compared Barbara Rothen-Rutishauser's interview and previous work with other researchers on nanoparticles in food.

3.5 Identify Resources Necessary for the Public to Gain an Informed Understanding of Nanoparticles in Food

To identify the necessary resources the public requires to gain knowledge of nanoparticles, we identified the commonly used methods to convey the information to Swiss public and assessed the methods the Swiss public currently uses. We accomplished this through interviews; one with members of the Swiss public and one with a communications expert, Christine D'Anna Huber.

We conducted a semi-structured 30-minute Zoom interview with communication expert Christine D'Anna Huber. Christine D'Anna Huber is an independent science journalist who works closely with institutions such as the Switzerland National Science Foundation. She is also the Secretary General of the Swiss Association of Science Journalists. The questions we asked included: "What forms of media are most accessible to the public when presenting educational content?" and "What type of document structure is the most appealing to the public?" A full list can be found in **Appendix C** and a transcription of the interview can be found in **Appendix G**. We used this interview to obtain an expert perspective on how information should be structured to make it engaging with the public in order to provide recommendations for furthering this project's goal after its completion.

4. Results and Discussion

After completing the content analysis, surveys, and interviews we have determined the following results concerning the Swiss public's knowledge and opinion on nanoparticles in food:

1. Most media published about nanoparticles are not written in layman's terms and are therefore less accessible to the general public.
2. The small population sampled is overall unaware of nanoparticles used in food; instead the public is focused on microplastics contaminating food products.
3. The sampled population is not representative of the entire Swiss population but provides reasonable insight on the knowledge and opinions of Swiss public ages 55 and under.
4. The public needs to develop a clear distinction between nanoparticles and microplastics in food.

In the following sections we will present the results collected from each objective that lead us to this conclusion.

4.1 Media on Nanoparticles in Food

After reviewing a variety of Swiss published media such as newspapers, advertisements, and magazines we found that most Swiss media about nanoparticles is not written in layman's terms and is therefore not easily accessible to and accessed by the general public.

In a majority of the reviewed articles, the attitude toward nanoparticles is slightly negative. Often the articles referred to lack of research on the long-term effects as reason for concern. The articles published by more science-based organizations tended to convey a more positive attitude that was supported by cited references. Contrarily, in almost all the articles written in layman's terms, very little information on nanoparticles is presented to the reader.

The sources about nanoparticles used in this content analysis were limited. There were very few articles written in layman's terms and even fewer published in wide-reaching media such as newspapers and magazines. The majority of published materials on nanoparticles are academic papers which were not useful for this portion of the project. The published media about nanoparticles were also not restricted to those used in foods. The actual subject of articles

dealing with nanoparticles ranged from unintentional nanoplastics in water to unlabeled nanoparticles in food products.

We believe that some of the confusion and lack of knowledge around nanoparticles comes from microplastics having a larger media presence. In recent years there have been a number of articles on microplastics published in the mainstream media. These publications were mainly about the harmful and unintentional effects microplastics have on the environment and on public health. Due to the similar size of microplastics and nanoparticles, the public often confuses the two.

This content analysis has shown that nanoparticles are seldomly considered by the general public and are often misrepresented in the media. Through this content analysis we gained a general idea of what type of information the Swiss public has easy access to about nanoparticles. This is reflected by the responses we received to the public opinion survey.

4.2 Knowledge and Opinion on Nanoparticles in Food of a Small Sample Population

4.2.1 Freelisting Survey

The results of this survey align with the results of the content analysis of the Swiss media. A large portion of those surveyed knew very little about nanoparticles or confused nanoparticles with microplastics. We received 279 responses to the freeling survey, including responses to this question: "Would you please list all of the things that you can think of when you hear 'nanoparticles in food'?" These responses varied from one word to a few sentences. The topics covered and the overall connotation of each response was recorded and compiled. **Figures 2** and **3** summarize the overall data.

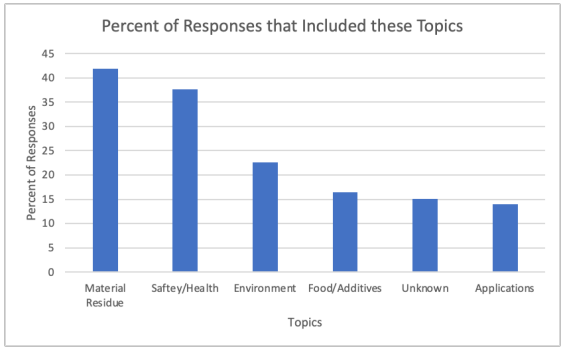

Figure 2: *Freelisting survey: Summary of topics covered in the survey response.* Many participants listed multiple topics, which were tallied separately.

As shown in **Figure 2**, over 40 percent of the participants listed different types of material residue that inevitably ended up in food, which include heavy metals and plastics. One hundred out of the 279 responses listed plastic. Interestingly the second most commonly listed topic in the freelisting survey was the concern about the safety/health impacts of nanoparticles in food. The majority of these concerns were about microplastics, even though they are not nanoparticles nor are they specifically added to food. The third most commonly listed topic was related to the environment, and again the majority of these responses were concerns about pollution related to microplastics.

The most commonly mentioned topic that did not pertain mainly to microplastics is labeled in **Figure 2** as "Food/Additives." This is when a specific nanoparticle additive or food containing nanoparticles was mentioned, but even a few of these responses included comments on microplastics. From these responses it is evident that those surveyed are conflating microplastics that end up in food with nanoparticles that are purposefully added into food.

Additionally, 15 percent of respondents said that they did not know much if anything about nanoparticles in food. Only 14 percent of respondents listed any specific application of nanoparticles, so it is clear that the benefits nanoparticles can provide are not being widely advertised.

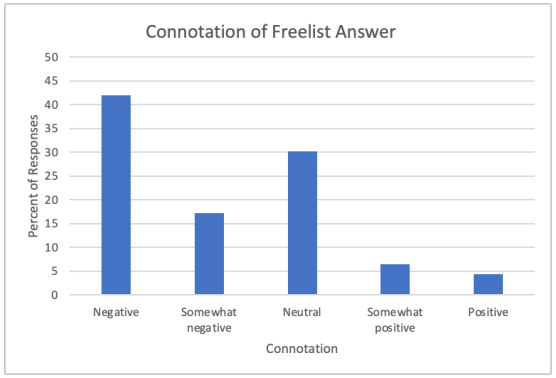

Figure 3: *Freelisting survey: Summary of the connotation of responses.* Each response was assigned a connotation.

The general opinion of respondents to the survey on nanoparticles in food was determined by the "connotation," the overall tone of each participant's response, from negative to positive (**Figure 3**). Overall the majority of responses were negative or neutral, very few people had a positive or slightly positive response (10.8%). It is also important to consider that a number of the responses were about microplastics or other material residues in food, and not specifically about engineered nanoparticles that were added to food. This means that the survey response may not reflect the public's opinion on nanoparticles in food, because they may not have understood what nanoparticles are. Furthermore, the responses that more accurately listed information on nanoparticles tended to be more positive than the overall results.

4.2.2 Second Public Opinion Survey

The second public opinion survey was completed to examine whether *specifically* asking about nanoparticles that are *intentionally* added to food affected the public's rated opinion of the use of nanoparticles in food. The initial survey population was more limited for this survey because it could only be sent out to the associates of the Adolphe Merkle Institute.

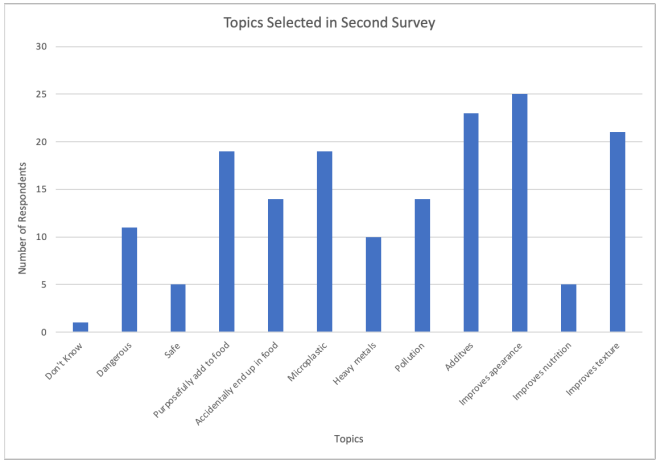

Figure 4: *Second survey: Selected topics associated with nanoparticles in food.* In the survey, the items listed under "additives" were "silicon dioxide, titanium dioxide, or other additives."

The second survey only received 32 responses; **Figure 4** depicts the number of responses who selected each topic when asked to check off topics they associate with nanoparticles in food. Unlike the freelisting survey, more participants said that they associated nanoparticles in food with our list of specific additives and some of our listed improvements. Fewer respondents selected a topic specifying whether they are safe or dangerous of nanoparticles in food. One similarity between the freelisting survey and the second survey is that microplastics were commonly specified. Another interesting result is that more people in this survey agreed that nanoparticles could be purposefully added into food. These differences in results were probably due to the decreased diversity in respondents, because the majority of the respondents to this survey work with nanoparticles.

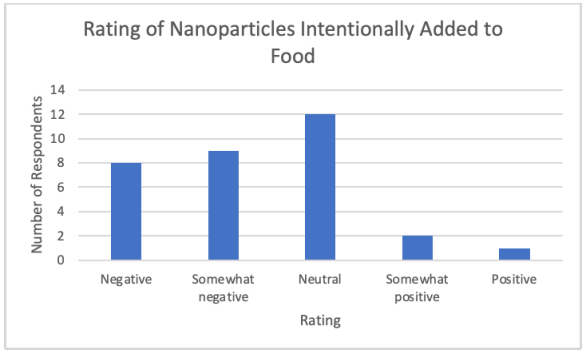

Figure 5: *Second survey: Participants' rating of nanoparticles intentionally added to food.*

Unlike in the freelisting survey, the second survey specifically asked participants to rate their opinion of nanoparticles that are intentionally added to food. **Figure 5** depicts the distribution of ratings from this survey. The most common rating was "neutral," but more participants rated their opinion as "somewhat negative"/"negative." Only three people rated nanoparticles intentionally added into food as "positive" or "somewhat positive." In both surveys the most common responses were "negative"/"somewhat negative" or "neutral." This indicates that specifying referring to nanoparticles that are intentionally added to food did not change the perception of the participants. Moreover, even with the exclusion of material residue, many of the participants still rated their opinion of nanoparticles in food as "negative" or "slightly negative." People may be fearful of nanoparticles in food due to their lack of knowledge of the state of nanoparticle research, and the prevalence of references of unintentionally added nanoparticles in the media.

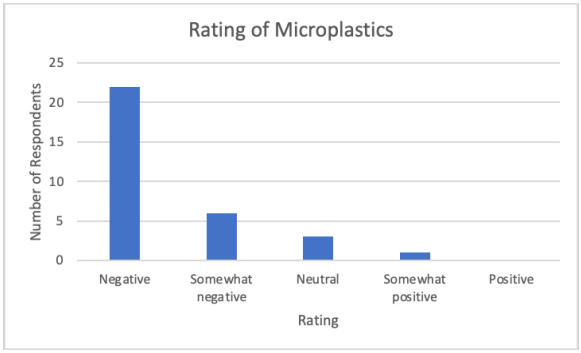

Figure 6: *Second survey: Participants' rating of microplastics.*

The second survey also asked participants to rate their opinion of microplastics; the results are summarized in **Figure 6**. As expected, the majority of responses rated microplastics as "negative" and the second most common response was "somewhat negative." Interestingly, one response rated microplastics as "somewhat positive." As shown by these results, the overall opinion of microplastics is very negative. Therefore because microplastics and nanoparticles in food are commonly confused by the public, the overall opinion of nanoparticles in food is probably more negative than if the public considered the two to be different..

4.2.3 Public Interview and Longform Survey

When asked "Have you ever heard of nanoparticles?" all participants responded that they had (exact response can be found in **Appendices H** and **I**). Despite all having heard of nanoparticles, most participants were unable to describe how nanoparticles are used in food. Only one participant was able to list some of their uses in food. Even the one participant who had received university level education in applied physics and learned about nanostructures and technologies was unaware of the use of nanoparticles in food. These results show that even those who have learned of and have studied areas involving nanoparticles are unaware of their use in food products.

The survey included a question asking when or where they had learned of nanoparticles. One participant admitted to thinking that "nanoparticles" was another word for "microplastics" until taking the survey and being asked about each individually. This is further indication that the

public frequently misinterprets nanoparticles for microplastics and has formed an opinion only on the information they know about microplastics.

In contrast to the question on nanoparticles, when asked “Have you ever heard of microplastics and what do you know about it?” all participants were able to describe where microplastics are found and/or how they are formed. This is likely due to the prevalence of microplastics appearing in public media in association with pollution. The public is therefore not well informed on nanoparticles, let alone about intentionally added nanoparticles in food. Nanoparticles are commonly confused with microplastics and are thought to be unsafe.

Combining the results of the surveys and the interview, it is evident that the public knows little about the difference between intentionally and unintentionally added micro/nanoparticles, which results in confusion between intentionally added nanoparticles and microplastics. This confusion leads to the public having a negative opinion of nanoparticles present in food products. These results may not reflect the entire Swiss population as they are from a small and concentrated sample, but this is assessed in the next section.

4.3 Comparing Our Sample with the Swiss Population as a Whole

Tables 1, 3, 5, and **6** (below) summarize the overall demographics of the freelist survey population. **Tables 2, 4,** and **7** (below) summarize the overall demographics of the second survey population.

4.3.1 Survey Demographics

Age (years)	Number of Responses	Percent of Responses
24 and under	191	68.5%
25-54	86	30.8%
55-65	2	0.7%
65 and older	0	0.0%

Table 1: *Freelisting survey: The age distribution of the respondents.*

Age (years)	Number of Responses	Percent of Responses
24 and under	2	6.3%
25-54	27	84.4%
55-65	3	9.4%
65 and older	0	0.0%

Table 2: *Second survey: The age distribution of the respondents.*

The freelisting survey population was very young compared to the overall Swiss population; more than half the individuals surveyed were 24 and under (**Table 1**). In contrast, 84% of the second survey population was 25-54 (**Table 2**). Neither survey included any participant 65 and over. A survey from 2014 reported that 18% of the Swiss population was 65 and older (Federal Statistics Office, 2015, p. 23). Our surveys’ lack of older participants must be taken into account when attempting to extend its results to the general Swiss population. However people ages 24 and under are budding consumers and are more likely to change their purchasing habits. Additionally, people ages 54 and younger are the majority of the population (Federal Statistics Office, 2015, p. 23). Because our survey results cover people ages 54 and under this is fairly representative of the consumer market.

Highest Education Achieved	Number of Responses	Percent of Responses
Secondary School	121	43.4%
Bachelor’s	113	40.5%
Master’s	41	14.7%
PhD/MD	4	1.4%

Table 3: *Freelisting survey: The distribution of the respondents’ highest educational level achieved.*

The majority of the respondents in the freelisting survey highest level of education reached is secondary school or a Bachelor’s degree (**Table 3**). Many of the respondents who said they had a secondary school degree specified that they were in the process of pursuing a

Bachelor's degree. This may not be the case in the general population because careers do not require a Bachelor's degree.

Highest Education Achieved	Number of Responses	Percent of Responses
Secondary School	5	15.6%
Bachelor's	3	9.4%
Master's	10	31.3%
PhD/MD	14	43.8%

Table 4: *Second Survey: The distribution of the respondents' highest educational level achieved.*

Unlike the freelisting survey, a large percentage (44%) of respondents from the second survey had a PhD or MD and only 25% had a Bachelor's degree or less education (**Table 4**). This representation of PhD/MDs is likely to be drastically different from the demographics of the general Swiss population.

Because both the surveys were distributed to a university population, the survey participants probably included more academics than in the general Swiss population. Individuals who work and/or study in academia tend to be more familiar with academic journals, which are currently the only type of media that mention and explain nanoparticles purposefully added into food. The greater likelihood of exposure to scientific research could mean the surveyed population is more likely to know something about nanoparticles in food, although it did not appear to be that way.

Field of Work or Study	Number of Responses	Percent of Responses
Social Science	98	35.1%
Law	41	14.7%
Technology	39	14.0%
Education	34	12.2%
Medical/Health	32	11.5%
Administration/Business	18	6.5%
Community/Social Services	9	3.2%
Other	6	2.2%
Not Specified	5	1.8%

Table 5: *Freelisting survey: The distribution of the respondents' field of study or work.* The technology includes math, science, engineering, and computer science.

One advantageous demographic of the freelisting survey is that individuals surveyed have a large variety in backgrounds and fields of study (**Table 5**), consistent with the general Swiss population. This aids in the applicability of the results to the general Swiss population.

Work/Study Involves Nanotechnology	Number of Responses	Percent of Responses
Yes	22	7.9%
No	256	91.8%
Not Specified	1	0.4%

Table 6: *Freelisting survey: The distribution of the respondents whose work or study involves nanotechnology.*

Table 6 records the number of respondents to the freelisting survey whose work or study involves nanoparticles. Compared to the second survey, many fewer respondents work with or study nanoparticles, only 7.9%. However, this might be higher than the average of the Swiss

population. In any case the vast majority of the respondents do not have a personal link with nanoparticles.

Work/Study Involves Nanotechnology	Number of Responses	Percent of Responses
Yes	21	65.6%
No	11	34.4%

Table 7: *Second survey: The distribution of the respondents whose work or study involves nanotechnology.*

Conversely, the majority (65.6%) of the second survey respondents' field of work or study involves nanotechnology (**Table 7**). This means that more of this survey population could have a closer connection to nanoparticles in food, but as noted in the previous objective those who work or study nanotechnology do not necessarily know about nanoparticles being intentionally added to food. Interestingly, confusion between intentionally and unintentionally added nanoparticles is even prevalent among those who study nanotechnology (refer to **Figure 11**), as well as the confusion of intentionally added nanoparticles with microplastics.

Another consideration is that our survey populations are at least primarily from one Swiss canton, Fribourg. Switzerland has four official languages, French, Swiss-German, Italian, and Romansh, each with their own culturally unique population. Fribourg is one of the few cantons with two official languages and therefore may be more representative of the entire Swiss population than a single-language canton. Fribourg is a primarily Swiss-German and French–speaking canton, which are the two most commonly spoken languages in Switzerland (European Commission, 2020). Therefore our data from Fribourg may be more representative of the Swiss population as a whole than data collected in another canton.

4.3.2 Comparison Freelisting Survey Results and Demographics

To assess whether the generalization of our results to the entire Swiss population is reasonable, we examined the inconsistencies between our sample populations and Swiss population. We compared the specific demographics of the freelisting survey to the topics covered in the response and the overall connotation of the response (**Figures 7-12**). The demographics we compared were age, education, and whether they work or study nanoparticles.

The second survey responses were not compared in this manner because the sample size of 32 was too small for an accurate comparison.

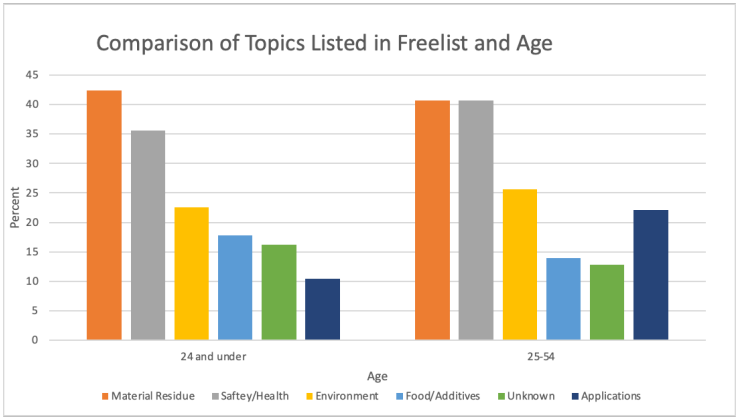

Figure 7: *Freelisting survey: Comparison of topics listed and age.* Two participants were over 55 but the sample was too small for an accurate comparison.

We compared the topics covered in responses of participants aged 24 and under to those who were 25-54; note that we did not consider the two participants who were over 55 because the sample was too small for an accurate comparison (**Figure 7**). We found that the two most common topics brought up in both age groups was material residue and safety/health. The same number of participants aged 25-54 lists contained topics related to material residues and safety/health. This indicates that the confusion between microplastics and nanoparticles in food are similar across the two populations. The major difference between the two age groups is that older age group listed specific applications of nanoparticles in food more frequently. This is probably because fewer of them said that they did not know much about nanoparticles in food.

The takeaway is the commonality of confusing microplastics and nanoparticles in food is constant across age groups.

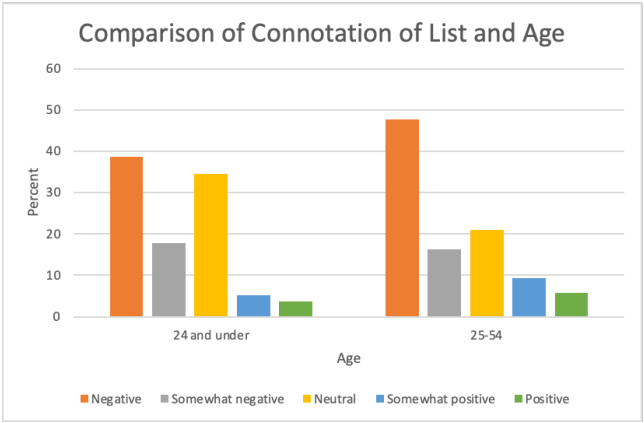

Figure 8: *Freelisting survey: Comparison of connotation of the list and age.* Two participants were over 55 but the sample was too small for an accurate comparison.

We also considered the connotation of each participant's response by age group (**Figure 8**). In both age groups (24 and under, 25-54), we classified the plurality of responses as negative, with neutral being the second most common. Furthermore, both age groups have very low percentages of responses that we categorized as positive or somewhat positive. The one key difference between the age groups is the percent of responses that were neutral are lower in the 25-54 age group and the percent of negative responses was higher. Although the shapes of the graph for each age group are very different, the majority of responses in both range from negative to neutral. Fisher's exact test resulted in a p-value of 0.119, which is greater than the set alpha value of 0.05, therefore the null hypothesis cannot be rejected. This means that age and connotation of freelist response may be linked or independent of each other. It is possible that the age of a person is linked to their opinion of nanoparticles in food.

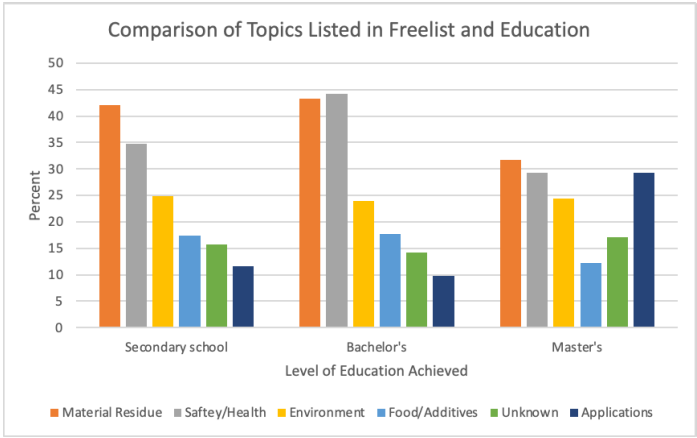

Figure 9: *Freelisting survey: Comparison of topics listed and highest education achieved.* Four participants had a MD or PhD, but the sample was too small for an accurate comparison.

Figure 9 is a comparison of the highest level of education achieved and the topics discussed in the freelist (four participants had a PhD or MD, but these responses were not included). The shape of the graphs for secondary school and Bachelor's degree are very similar except that safety/health was mentioned slightly more than material residue for those who have achieved a Bachelor's degree. The response distribution for those who have achieved a Master's degree is different. Material residue and safety/health are still among the most mentioned topics, but applications of nanoparticles in food were listed more often than in the other groups. This indicates that those whose highest level of education is secondary school or a Bachelor's degree may have less knowledge about the applications of nanoparticles in food than those who have achieved a higher degree.

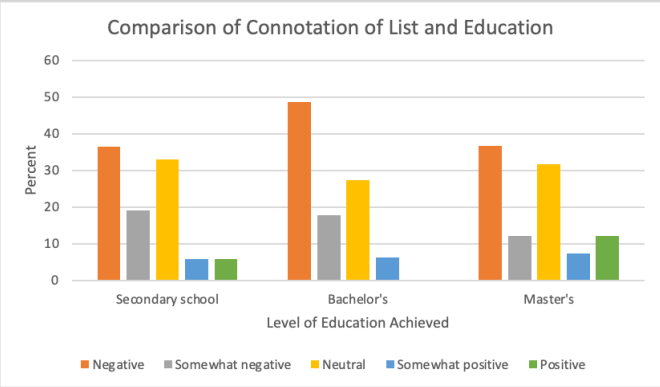

Figure 10: *Freelisting survey: Comparison of connotation of list and highest education achieved.* Four participants had a MD or PhD but the sample was too small for an accurate comparison.

Highest level of education achieved and the connotation of the freelist response were also analyzed (**Figure 10**). The distribution of assigned connotation for all three education levels are similar; for all three levels negative was the most common connotation, followed by neutral. The greatest difference between the levels of education is in the responses with a positive connotation; over ten percent of those who have achieved a Master's had a positive connotation, while zero percent of those who have achieved a Bachelor's responses had a positive connotation. The calculated p-value for Fisher's exact test was 0.033 which is less than the select alpha value, 0.05, therefore we can conclude that level of education and the connotation of the response are linked with only a 3.3% chance that they are independent.

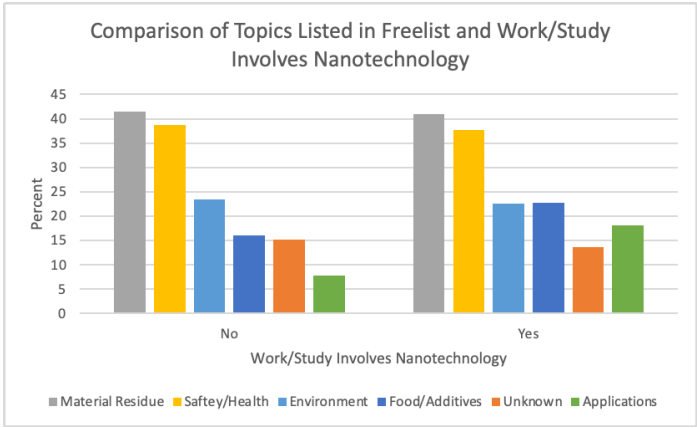

Figure 11: *Freelisting survey: Comparison of topics listed and whether the participant works or studies nanotechnology.* One participant did not specify if their work or study involved nanoparticles, their response was not included in this graph.

The last demographic we compared was whether the participant's work or study involved nanotechnology. **Figure 11** compares this demographic to the topics covered in their responses to the freelist survey (as one respondent did not specify whether their work/study involved nanotechnology, that individual's response was not included in this comparison). The shape of the graph for both those who do work or study nanotechnology and those who do not are similar. It is also important to note that only 22 of the survey's 279 respondents stated that their work or study involved nanotechnology. This number is so small that these results could be skewed, therefore a larger sample would be necessary to make accurate conclusions if distribution of survey topics mention accurately represent the actual demographic population.

One of the most interesting things is that in both populations, the two highest topics discussed were material residue and safety/health. This means that even people who work or study in a field of nanotechnology may not realize that there are nanoparticles that are purposefully added into food to improve its properties. One slight difference between the two populations is that those who said "yes" mentioned an application of nanoparticles more often than those who said "no." Perhaps some of the individuals who work or study nanotechnology

may focus on food applications and therefore they would be more likely to list applications in their response.

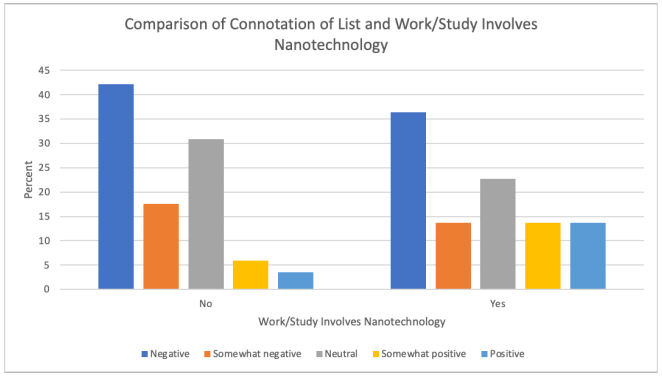

Figure 12: *Freelisting survey: Comparison of connotation of list and whether the participant works or studies nanotechnology.* One participant did not specify if their work or study involved nanoparticles, their response was not included in this graph.

Figure 12 compares the assigned connotation of the freelist response to whether a person's work or study involves nanotechnology. For both groups the two most common connotations are either negative or neutral, but those who work or study nanotechnology have a higher percentage of positive or somewhat positive responses. This higher positive response rate is probably due a larger percentage of respondents understanding the research and safety of nanoparticles added specifically into food. The Fisher's exact test p-value was 0.114. This leads us to conclude that whether a person's work or study involves nanotechnology may be independent or linked to the connotation of their freelist response, since the p-value is greater than 0.05.

Both surveys were sent out in a single email message that included an English, French, and German version. Many of the replies to the open-ended question of the freelisting survey were not given in the same language as the version of the survey the respondent was replying to. (For example a person may have responded to the French version using both English and French.) This made it difficult to evaluate the survey responses based on the version/language of

the response. Also French, English, or German may not have been the recipient's native language. The concern about material residue and microplastics was common across all three versions of the freelisting survey.

The second survey responses also could not be evaluated by language for the same reasons, and also because too few people filled out the French (four) and German (two) versions.

Across all demographics the two most common response topics are material residue and health/safety, and the majority of the connotations of the responses are either negative or neutral. This leads us to conclude that although our population is not very representative of the entire Swiss population it does provide reasonable insight into the entire Swiss population's idea of what nanoparticles are and how they feel about them. One issue is that this survey only includes two individuals over the age of 54. Therefore, it may not reflect the opinion and knowledge of the older population. With this caveat however, we determined that the surveys probably provide reasonable insight into the general knowledge—including errors of knowledge—of nanoparticles in food for people in Switzerland under the age of 55.

4.4 Information the Public Should Know

To answer some of these questions we conducted a semi-structured interview with nanoparticle expert Dr. Barbara Rothen-Rutishauser on September 21, 2020. A transcription of the interview can be found in **Appendix F**. This interview provided us with an expert opinion of what information should become general knowledge. For the Swiss public to be well informed about nanoparticles they should know what nanoparticles are, their properties, size, and why they are added to consumer products. This information would help define nanoparticles for the public and increase the distinction between them and microplastics.

Another point to clarify with the public is the matter of safety. "[The Swiss public] also should know that there are no hazardous effects of the particles used in consumer products" says Dr. Rothen-Rutishauser. By including this information we hope to address any concerns the public may have before they make their own conclusions.

4.5 Resources Necessary for an Informed Understanding

In the second survey we asked participants "Which of the following is your preferred method to learn about a scientific topic?" with the options of newspaper, website, public radio,

YouTube or other video platform, social media, and a write-in answer. The results of this question can be seen in **Figure 13** below.

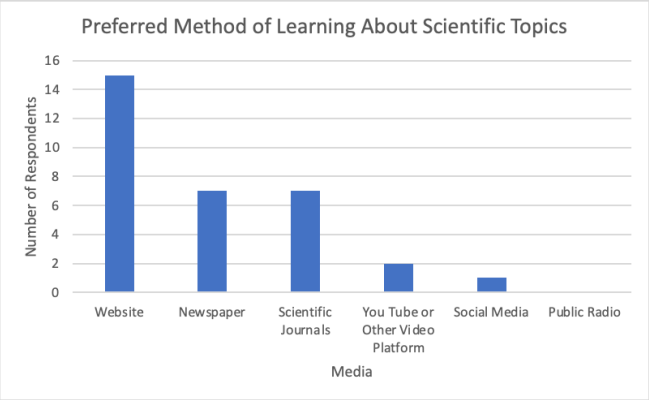

Figure 13: *Second survey: The public's preferred learning method for scientific topics.* A significant number of respondents have received PhD level education.

Results of the survey indicate that this educated public would be most interested in learning via a website or a newspaper. Scientific journals also received a significant number of responses but since 52% of participants in this survey had received a PhD, we believe this category is not representative of the Swiss public. These results were used to make our recommendations.

In completing this objective, we also conducted an interview with a communications expert, Christine D'Anna Huber. The results of this interview were combined with the survey results to form our recommendations for furthering this project.

5. Conclusion and Recommendations

After conducting a literature review, interviews, and surveys we have found that the public has limited knowledge of nanoparticles added to food and conflates nanoparticles in food with microplastics. The majority of the Swiss public's opinion of nanoparticles in food is negative or neutral, but this opinion better reflects the public's opinion of microplastics due to the confusion between the two. This confusion about nanoparticles in food can be explained by its relatively small amount of coverage in mass media, while microplastics are mentioned much more frequently. Due to the media coverage of microplastics, the public associates any small particle with pollution and plastics accumulating into food. Our recommendation is that the Adolphe Merkle Institute should work with communication experts to design media for the general public that will emphasize the distinction between nanoparticles, which are specifically engineered and added into food to create more appealing traits, and microplastics, which are plastic residue that accumulates on or in food products.

5.1 Possible Implementations of Recommendation

We recommend an increase in media about nanoparticles used in food to create a distinction between nanoparticles and microplastics. On September 23, 2020, we conducted a semi-structured interview with Christine D'Anna Huber, a communications expert, to gain insight on how media is produced for the Swiss public. A transcript of the interview can be found in **Appendix G**. With the information from this interview, we recommend the media produced to be multi-platform to reach the largest audience. Christine D'Anna Huber suggests public radio as one of those platforms as it is widely used in Switzerland.

To increase the amount of media coverage about nanoparticles, journalists must be informed on the topic. As suggested in conversation with our sponsor Dr. Ana Milosevic, we recommend that the Adolphe Merkle Institute hold a workshop event for science journalists. The purpose for this event being to inform science journalists about nanoparticles and their usage in food products. After the journalists have this information, they would be able to publish content on nanoparticles thereby increasing the amount of information about nanoparticles in the media available to the public.

Combining the results of the interview with Christine D'Anna Huber and the question on preferred learning method from the second survey, we recommend increasing the media coverage of nanoparticles via a multi-platform approach. We have found that the most requested and recommended platforms are public radio, newspapers, and websites. A workshop for science journalists is also recommended as an initial step in spreading information on the use of nanoparticles in food products.

5.2 Methods to Improve Research

We also recommend that further research should be conducted to understand if and how the public's opinion of nanoparticles in food has shifted. This could be accomplished through additional surveys. The survey we conducted in this project was a starting point to gain a reasonable understanding of the public's opinion of nanoparticles. But it can be improved upon. We recommend the following modifications.

Our survey results were crucial to understanding that the public commonly confuses nanoparticles with microplastics, but further improvements can be made to this study. Because our study only surveyed people associated with or close to the University of Fribourg, in the canton of Fribourg, our samples were not entirely random. Since the goal of the study was to determine the opinion of the Swiss public as a whole, expanding the survey to include other cantons would make the survey results more representative. We recommend conducting 26 different surveys, one in each canton, with a sample size relative to the population of the canton. This will ensure that every region is represented and researchers would be able to identify any differences in opinion or knowledge depending on the region.

Another important consideration for future surveys is that they should be given in the official language or languages of the canton. This project sent out the surveys in three languages, English, French, and German, and the last two of which are official languages of the canton of Friboug. This ensured that the survey was accessible to the population which was being surveyed and it allowed as many responses as possible. Surveys covering all of Switzerland should therefore also include Italian and Romansh.

Future surveys could be improved upon by including individuals who are older than 65 as well as those who are younger. This modification would make the survey more representative of the Swiss population and gain a broader knowledge of the public as a whole.

These recommendations should allow the institute to clarify the distinction between nanoparticles in food and microplastics, and to outline a method to test whether this clarification has resulted in changes in the public's opinion about and level of knowledge of nanoparticles. Additionally, our identification of the current low level of knowledge in Switzerland about nanoparticles in food and our identification of the Swiss public's conflating nanoparticles with microplastics, provides a broader understanding of the subject than previous research. This project presents recent data on the public opinion of nanoparticles in Switzerland, replacing older studies from 2008-2015. For the continuous and increased use of nanotechnology in food, the public needs to have access to information about nanoparticles that are specifically added into food products and a significant number of research projects need to be continuously conducted to assess and insure the safety of these foods.

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Appendix A: Freelist Survey Guidelines

Under the lead of the Adolphe Merkle Institute, Switzerland, this group from the Worcester Polytechnic Institute in Massachusetts, USA, would like to invite you to participate in a survey. This survey is part of a project in which we investigate better ways to inform the public about nanoparticles in food. We also research how to provide information about current legislation and where to find more information. The answers you give will be recorded and used to develop a deliverable (a brochure or a web site) as part of our project. Any personal information you provide will not be used in our final report; it will only be used to set up further interviews and focus groups. Our goal is to determine what the public currently knows about nanoparticles in food and how they feel about the topic. This survey should take five minutes. Your responses will be used to determine general knowledge of nanoparticles and what is important to the public to know about them. Names or any personal information of participants will not be included in our final published report. This survey is completely voluntary, and you have the right to skip any questions that you do not want to answer. You are also free to ask further questions that you may have regarding this survey before you begin.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: The Nanoparticles in Food IQP Group (Email: gr-nanoparticlesa20@wpi.edu) IRB Manager (Ruth McKeogh, Tel. 508-831-6699, Email: irb@wpi.edu) and the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

1. Which age group do you belong to?
    a. 24 and under
    b. 25-54
    c. 55-64
    d. 65 and over
2. What is the highest level of education you have reached?
3. What field do you work or study in?
4. Does your job or area of study involve nanoparticles or other forms of nanotechnology?

    a. Yes
    b. No
5. Would you please list all of the things that you can think of when you hear “nanoparticles in food”?
6. Would you like to come in for a longer interview?
7. If yes to the previous question please provide contact information below:

Appendix B: Second Public Survey Guidelines

Under the lead of the Adolphe Merkle Institute, Switzerland, this group from the Worcester Polytechnic Institute in Massachusetts, USA, would like to invite you to participate in a survey. Individual responses will not be reported, only compiled with the other data. Our goal is to determine what the public currently knows about nanoparticles in food and how they feel about the topic. This survey should take five minutes. Your responses will be used to determine general knowledge of nanoparticles. This survey is completely voluntary, and you have the right to skip any questions that you do not want to answer. You are also free to ask further questions that you may have regarding this survey before you begin.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: The Nanoparticles in Food IQP Group (Email: gr-nanoparticlesa20@wpi.edu) IRB Manager (Ruth McKeogh, Tel. 508-831-6699, Email: irb@wpi.edu) and the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

1. Which age group do you belong to?
    a. 24 and under
    b. 25-54
    c. 55-64
    d. 65 and over

2. What is the highest degree you have achieved?
    a. Secondary School
    b. Bachlers
    c. Masters
    d. PhD or MD

3. Does your job or area of study involve nanoparticles or other forms of nanotechnology?

    a. Yes
    b. No

4. Please check each of the following topics that you associate with nanoparticles in food.
    a. I do not know what they are
    b. Dangerous
    c. Safe
    d. Purposefully add to food
    e. Accidentally end up in food
    f. Microplastic
    g. Heavy metals
    h. Pollution
    i. Silicon dioxide, titanium dioxide, or other additives
    j. Improves the appearance of food
    k. Improves the nutrition of food
    l. Improved the texture of food

5. Please rate your opinion on nanoparticles that are intentionally added to food.
    a. Negative
    b. Somewhat negative
    c. Neutral
    d. Somewhat positive
    e. Positive

6. Please rate your opinion of microplastic.
    a. Negative
    b. Somewhat negative
    c. Neutral
    d. Somewhat positive
    e. Positive

7. Which of the following is your preferred method to learn about a scientific topic?
    a. Newspaper
    b. Public Radio
    c. Website
    d. YouTube or other video platform
    e. Social Media
    f. Other (list)

Appendix C: Interview Guidelines

Under the lead of the Adolphe Merkle Institute, Switzerland, this group from the Worcester Polytechnic Institute in Massachusetts, USA, would like to invite you to participate in an interview. This interview is part of a project in which we investigate better ways to inform the public about nanoparticles in food. We also research how to provide information about current legislation and where to find more information. The answers you give will be recorded and used to develop a deliverable (a brochure or a website) as part of our project. Any personal information you provide will not be used in our final report; it will only be used to set up further interviews and focus groups. Our goal is to determine what the public currently knows about nanoparticles in food, how they feel about the topic, and how they stay informed. This interview should take thirty minutes and will be audio recorded. Your responses will be used to determine the general public knowledge of nanoparticles and their concerns. Names or any personal information of participants will not be included in our final published report. This interview is completely voluntary, and you have the right to skip any questions that you do not want to answer. You are also free to ask further questions that you may have regarding this interview at any time.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: The Nanoparticles in Food IQP Group (Email: gr-nanoparticlesa20@wpi.edu) IRB Manager (Ruth McKeogh, Tel. 508-831-6699, Email: irb@wpi.edu) and the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

Public

1. Do you have any food allergies or dietary restrictions, if so what are they?
2. Have you ever heard of nanoparticles?
3. Do you know what they are used for?
4. Have you ever heard of microplastic and what do you know about it?
    a. [explain difference if not know between nanoparticles and microplastic]

5. Have you seen nanoparticle labels on food packaging such as this one and do you know what it means?
6. If you did, did this label influence your decision to purchase that food, why or why not?
7. What is your opinion or impression about nanoparticles in food products?
8. Do you know where/when you learned about nanoparticles?

Expert on Public Opinion

1. What is your past work experience with nanoparticles and their policies?
2. From your experience, what do you think is the public's overall perception of nanoparticles?
3. What are politicians over perception of nanoparticles?
4. The goal of our project is to provide the Swiss public with resources to further their understanding of nanoparticles and their benefits to the food industry. We plan to design a deliverable to help achieve this goal. What would your recommendations be for this deliverable?

Nanoparticles Technical Expert

1. What information do you feel is important for the public to know about nanoparticles?
2. What is your opinion on the policy surrounding nanoparticles?
3. What is the state of current research of nanoparticles?

Communications Expert

1. What forms of media are most accessible to the public when presenting educational content?
2. What type of document structure is the most appealing to the public?
3. How can you improve public engagement?
4. The goal of our project is to provide the Swiss public with resources to further their understanding of nanoparticles and their benefits to the food industry. We plan to design a deliverable to help achieve this goal. What would your recommendations be for this deliverable?

Appendix D: Longform Public Survey Guidelines

Under the lead of the Adolphe Merkle Institute, Switzerland, this group from the Worcester Polytechnic Institute in Massachusetts, USA, would like to invite you to participate in a survey. This survey is part of a project in which we investigate better ways to inform the public about nanoparticles in food. We also research how to provide information about current legislation and where to find more information. The answers you give will be recorded and used in the final report of our project. Our goal is to determine what the public currently knows about nanoparticles in food and how they feel about the topic. This survey should take five minutes. Your responses will be used to determine general knowledge of nanoparticles and what is important to the public to know about them. Names or any personal information of participants will not be included in our final published report. This survey is completely voluntary, and you have the right to skip any questions that you do not want to answer. You are also free to ask further questions that you may have regarding this survey before you begin.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: The Nanoparticles in Food IQP Group (Email: gr-nanoparticlesa20@wpi.edu) IRB Manager (Ruth McKeogh, Tel. 508-831-6699, Email: irb@wpi.edu) and the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

1. Do you have any food allergies or dietary restrictions, if so what are they?
2. Have you ever heard of nanoparticles?
3. Do you know what they are used for?
4. Have you ever heard of microplastic and what do you know about it?
5. Have you seen nanoparticle labels on food packaging and do you know what it means?
6. If you saw that a product uses nanoparticles, would it influence your decision to purchase that food? Why or why not?
7. What is your opinion or impression about nanoparticles in food products?
    a. Positive
    b. Partly Positive

c. Neutral
d. Partly Negative
e. Negative

8. What is your reasoning for your opinion selected above?
9. Do you know where/when you learned about nanoparticles?

Appendix E: Transcription of the interview with Sergio Bellucci

September 24, 2020 at 9 am EDT

Rayna Harter interviewed Sergio Bellucci with Marika Bogdanovich acting as secretary.

Rayna Harter (RH): So for us, we've been focusing on the relationship between like public opinion on nanoparticles and specifically when they use them in food. And we're trying to figure out what the public opinion currently is and how we can educate the public on the things they should know about the legislation and about, like safety of the technology and just like, what it means in general, what it means to have nanotechnology in food.

Sergio Bellucci (SB): Okay, I'm just writing some key words. [Pause] So public opinion on nanotechnology is an important point and then how to educate people on what?

RH: Nanotechnology and basically what it is and what they should know from the recent scientific research and legislation standpoint.

SB: Okay So maybe I'll try to first give you an introduction about my connection to nanotechnology, to public opinion, legislation, politics, so that you have an idea. So I was the director of the Swiss Center for Technology Assessment for about 20 years. This organization is something similar to the OTA that you had in the United States many years ago; maybe you don't remember this organization. It's called the Office of Technology Assessment; they are working for the Senate and the United States. The idea is to advise politicians on new technology and to get a new, more independent [Pause] advice on the new technology. Exactly what you said about the research and about legislation, benefits of the new technology, risks of it. And this was also practiced in Europe for, now about 20 years. And we were working for the Swiss parliament, mainly for the politicians. Our work was mainly to advise the politicians on new technology, and nanotechnology was one of them. We were doing an interdisciplinary study on, for example nanotechnology, where we tried to evaluate the technical aspect, the medical aspect, but also the ethical aspect, regulation, legal aspect, just to have a full understanding and review for the politician. The

second important point was also to get the opinion of the Swiss population in the early stage. So when the technology was coming up, in Switzerland, not everything is clear and we don't know also how the acceptance for this new technology would be within the Swiss population. For example also what we discuss today; all this digitalization, artificial intelligence, also new technology that was denied in the early stage. To get the public opinion about this new technology and—just tell me if something's not clear. Regarding this opinion we were running different methods where the idea was to take a sample of the Swiss population and then discuss with them the possible benefits, risks, specialities, the use of this new technology. Then later discuss with them how they see it, how they react, where they see the positive aspect, where there are risks, what they have questions on, and which needs they have for the new technology. This was very, very short—the discussion of public opinion. Then when we had these results, these reports together we proposed some recommendations to the politician. We said "Listen, this is the opinion of the Swiss population on new nanotechnology. These are the risks, the benefits they see, the wishes they have." [Pause] Now I leave the floor open and we can discuss, you can give me some questions.

RH: So I see you've done a lot of work drafting that report with the public opinion. What did you actually find with the public opinion in that early stage?

SB: Well, it is also many years ago, about 10 years now, but at that time what I can clearly remember is that in general the Swiss population were open to nanotechnology. They had different lectures from specialists, from competent people in different sectors. People from science, from legislation, from health, also from consumer organizations. Finally they saw lots of benefits with the possible use and introduction of nanotechnology in Switzerland, but they had also some questions about their use. It was not so clear, and is still not so clear, what would be the long-term effects. They could be something toxicological, something negative for these particles. So they are of course careful when they use these nanotechnology. Especially if they have to take them in; for example medicine. External application is not so critical but when it goes into the therapies and use of medicine with this particle, especially if they don't know the long-term effects, they are afraid. What is very important to them is that they are really transparently informed. So the companies or the researchers or whoever communicate in an open way what really would be a problem or

not. So in this way they are really sensitive on this aspect. In general, they saw many positive applications and uses for this technology on this product. So we cannot say they are against; they are positive but they want to be informed, they want to be involved. About the use and about the future use and also future results. For example, if they have negative long-term effects, the people should be informed about this aspect.

RH: Okay and then we have one other big question. What did you find that the politicians wanted to like, convey to the public at that time?

SB: Well, in general they were happy that there was not a big controversy on the topic. In Switzerland there is a negative attitude for things like genetic engineering in the field of food. In nanotechnology we don't have this discussion, at least up till now. What was positive, for example what has been for the Swiss politician, there was a request to build a new law specifically for nanotechnology. So all these new substances that we introduce or could possibly be introduced didn't request a new law. This of course is an advantage to not have to make a new law specifically for this. Again I was saying the Swiss are especially sensitive to food. So if they have to eat something that can possibly have nanotechnology then they are really careful and want clear information on the possible negative aspects of this. For now we don't have them and we have to be careful what we see and discuss in Switzerland.

Appendix F: Transcription of the interview with nanotechnology expert; Barbara Rothen-Rutishauser

September 21, 2020 at 9 am EDT

Rayna Harter interviewed nanoparticle expert Barbara Rothen-Rutishauser with Marika Bogdanovich acting as secretary.

Rayna Harter (RH): Our first question is; what information do you feel is important for the public to know about nanoparticles?

Barbara Rothen (BR): I think that it is important to know what they are; so the properties, the size, why they are so small, why they are added to consumer products. And I think they also should know that there are no hazardous effects of the particles used in consumer products. Because there is a lot of misinformation going around with toxicity studies that have nothing to do with the consumer products. And I think that this is information that the public needs.

RH: I can see that because it's really funny. Everybody focuses on the stuff that isn't supposed to be the nanoparticles that just end up into food because of food chain stuff, and not the stuff that's being purposely put into it. I've noticed that all of the responses—I have a category for the environment and material residue. And a lot of people mention material residue related things. [Pause] And I also have a long list of people who said plastic; I have gone through 70 of the surveys and 23 of them have said plastic.

BR: Okay. I mean, yes there is nanoplastics but it is usually microplastic. So there is a big confusion about it with micro/nano.

RH: So then we want to like, also like—another aspect of our project is we're talking about policy surrounding nanoparticles and we were wondering what your opinion on the current policies are and if they are clear or unclear and how that helps with, helps or doesn't help the public.

BR: I think in Switzerland—so the policy is that we have to declare that consumer products contain nanoparticles. And it should be more clear to the consumers that this does not mean that something is hazardous. I repeat myself, but for many people the declaration is not clear what it means. So here the policymaker should emphasize more, that all consumer products which are on the market, they have undergone so many tests we could not—I as a company, I could not tell something if I did not show it's not toxic. So that people really need to be—that has to be confirmed that the declaration does not indicate that something has a toxic effect.

RH: Okay, so then we have one more question, because we had issues coming up with the questions because we are terrible people. Our last big question was: what is the current state of research of nanoparticles—like what have you like been like really like is there any like specific thing that you want the public to know about like what has been like beneficial to them just in general for research wise?

BR: I'm not really sure I understood your question. So from research, it is very clear that the use of cosmetic products or food products that there is not—that these products do not cause any harm to the people. So this is also—and there is a lot of research that has been done. What is known is that we should avoid inhalation of nanoparticles, so everything which is in the air, we should avoid inhaling. This is what we have shown in the last 10 to 20 years based on research results. [Pause] Was this the question? Or are you thinking more which direction it will go?

RH: For us it was like it was more of like we want to like more seeing like yeah that was important but we also want to know what direction you're going just to see if like it's going if we're going to continue to design products that are meant to be like, beneficial to the public.

BR: I mean the direction which my research is going is that we develop tissue models to study the chronic exposure. So if we eat or if we inhale something we are chronically exposed to very low nanoparticle concentrations. And if I go down to the real concentrations, I never see any effects. So my aim is really to develop models that I can use in the lab so I can predict the long-term chronic exposures to nanoparticles. And based on these findings which we have, we can confirm also what has been confirmed in vitro. So in

animal experiments or if humans are exposed and this is the direction we as researchers should move.

RH: From what we've read, from like the different like risk analysis, most of them said so far we haven't found anything and more research should be done to determine the chronic exposure because those take a long time.

BR: And I mean there is a lot of research ongoing with animals to look at ingestion; so if they give the nanoparticles into the food. There are many studies based on the current discussions, Europe and worldwide, and they do the experiments using real concentrations of nanoparticles and they do not see any effect. [Pause] Of course, if you give the animals a lot—it is like the alcohol or chocolate—that if you give a lot you will see effects. In all the studies done really with realistic concentrations—they of course have to calculate down to the weight of the animal and how many times they eat—they have not seen any effect.

Appendix G: Transcription of the interview with communications expert; Christine D'Anna Huber

September 23, 2020 at 9 EDT

Rayna Harter interviewed communications expert Christine D'Anna Huber with Marika Bogdanovich acting as secretary.

Rayna Harter (RH): We've heard that you are a journalist, correct?

Christine D'Anna Huber (CDH): That's correct and that's not correct. I am a journalist by education and study. I've worked as a journalist in public media for more than 20 years but now I am independent. I have a kind of communication business that I own. I'm mostly working for Swiss institutions, like the National Science Foundation, that need to—that have scientific reports that they have to give to policy makers but policy makers will not understand that kind of scientific language. So what I'm doing—I'm translating if you will—scientific speak into normal human being speak, so that the policy makers understand it. That's the main part of what I am doing now. And a lot of communication work for a lot of different institutions like for example; Contact Point Nano, which you know I think. I am also the Secretary General of the Swiss Association of Science Journalists. That's where science journalists but also science communicators work together and try to—I suppose it's the same in Canada also. It's getting more and more difficult for science journalists to find work because more and more newspapers' funds are being cut. There's no money anymore for science journalism. Which is nice to have for many newspapers but not really their priority so it's kind of a difficult time for science journalists. More and more of them become science communicators and we are trying to see if in some way we can solve it or protect science journalists and it still continues to be something that newspapers value. [Pause] That was a long answer for a short question.

RH: That's fine, we have plenty of time. So our project—we're focusing on like, communicating to the public about the like, benefits and how there's more to nanoparticles in food than just the nanoparticles that are being accidentally put into it from runoff and

waste things. And we want to focus on getting that out there because it seems that—from the research we've done so far—that's what people focus on; the environmental and residue aspect as opposed to the purposely added ones. So to start with our questions—we're actually making a deliverable—but to start; What forms of media, in your opinion, are most accessible to the public when presenting educational content?

CDH: Most accessible in what way? That people can easily—[Pause]

RH: Like easily see and what's traditionally used in Switzerland because I know it's very different that it is here in the U.S.

CDH: Okay, well we have a very good public radio and public TV. I know that in the United States that it is maybe 1 in 100,000 persons watching PBS; no, I'm exaggerating. But in Switzerland it's really something that is very mainstream and everybody watches public TV or listens to public radio. So that's a very good channel to educate if you want the public opinion about things.

RH: For online education we were more wondering what people do for online education. Do they make websites for people that are posted, or do they make pdf's and things like that, or what kind of formatting for that kind of stuff?

CDH: Well, all of the mainstream media also have websites of course. And more and more journalists are having to produce not only written content but also audio content or even videos. So it's—most media are kind of multi channel and use different supports to get their messages across.

RH: Okay, so we're planning, because we can't really like do something like really big, we were planning on doing either a webpage for the information or like a pdf document that could like get sent out by giving it to the Adolphe Merkle Institute to send out to people or to give out when they go to seminars when they go to secondary schools. And we were wondering what type of format for a document esk object would work best for accessing and being pleasantly pleasing to the Swiss public.

CDH: [Pause] Just to be sure to understand; your message is coming from whom? From the scientific institution or from a lobbyist group or I mean who is the sender of your message?

RH: Okay, so we're trying—we're working with the Adolphe Merkle Institute for our IQP and our IQP is like a project that our university does that you can do on campus or abroad and you work with a sponsor, whether that be an institute or a company or anything. Ours

is specifically with a university aspect and you work to a goal. Our goal for it is to get the public—to understand what the current public opinion is on nanoparticles in food is in Switzerland and to provide educational material so that they have access to the information that research is being done in companies so that they understand the subject.

CDH: So you are addressing the Swiss public?

RH: Yes.

CDH: Okay, and you want the Swiss public to have a better understanding of nanoparticles in food?

RH: Yes.

CDH: Okay. So what you would need to do probably is [Pause] I mean it's very difficult to get your message, one to one into the public media. No journalist will take what you provide, the content that you provide as is, but they will do their own story, take your information, maybe as one side and try to get another side or other sources. So no one will just take what you provide as is and put it in the mainstream media. So if you would like to pass your content more directly, probably public open tables or some kind of event where you would present your content and invite people. Then, of course, the problem is that you will have a limited audience. If you organize an event, maybe if you're lucky, you'll have 100 or 200 persons. So either you'll have to repeat that many times in order to get it to a larger audience. It's difficult. Or maybe a website where you can directly put your content on the way you would like it to be presented and then try to attract as many people to go on that website. Which is, of course, not easy. Well then everything depends on how attractive your content is made up, short videos are always good. It's nice if there's a bit of humor or—in any case, it mustn't be boring else you will lose your audience immediately. I'm trying to reflect, maybe there's examples—there's a lot of youtubers doing scientific communication. [Pause] I don't remember the precise name right now but you will be able to find them. That's a good way to get to a large public. But it's not easy, there is no easy piece to tell you to do this and this and this and mixed ingredients and then you will get perfect attendance from a certain number of people.

RH: We were thinking much more small scale. Like what our sponsor, Ana, had talked to us about was how they do informational sessions where they go and talk to young people and give them something to take with them after the session; something like that. So

something really small like just organising a pamphlet. For us, because we have no idea, like what types of how much text should be on there and things like that, depending on the way the Swiss read things compared to the US. We don't really know; that's more like what we were looking for.

CDH: Okay, okay. Well not too much text in any way. Maybe Ana can also provide something. Ana is also working Empower; it has a very good communications service and they do lots of pamphlets and things like that. They might be able to provide some examples. It's always very little text; it's a bit frustrating if you have very many things to say. But if you overfill it you will lose people. They will not read to the end, so it has to be colorful, it has to have nice images, it has to have not too much text, and the text must be accessible—nice to read. It has to be attractive so people will really read it from A to Z.

RH: Makes sense. [Pause] So our next question; you've already heard our goal which is to provide the Swiss public with resources to further their understanding of nanoparticles and their benefits to the food industry. We plan to design a deliverable to help achieve this goal. What would your recommendations be for the types of content we should include?

CDH: Include on what exactly?

RH: Like on a pamphlet, like to have some text and who to contact for more information and then have nice pictures on it. Would that be good?

CDH: That's good, yeah, that would be good. The more services you can provide like giving telephone numbers or emails where they can really reach out and get answers if they have questions. All that service, you know, all that added value is good. So not just text but text plus added value for services. Where they can get answers if they have questions or where they can consult a website or things like that.

RH: Okay, we also had a question about public engagement but I assume that will be a very similar answer. How can we improve the public's engagement in things? Because right now they seem to be ignoring that aspect of nanoparticles.

CDH: That's a tough one. Actually I've written the policy brief for the NRP64 which was a national research project funded by the Swiss National Foundation for Science. They actually had a task force because on one hand, everybody's afraid that nanoparticles will have the same bad reputation, if you will, as asbestos had. Which was a big scandal in Switzerland, at some time it was the revolutionary new material that everybody wanted to

use and then oops. Some years later all the problems came out. So people are, and researchers also, and politicians and policy makers—people who are convinced nanoparticles are revolutionary and will bring a lot of good opportunities and a lot of applications are a little bit afraid that the public opinion might turn. So for the moment some people are quite content that the public doesn't pay too much attention to nanomaterials. With the NRP64 program they actually had a task force standing by and observing newspapers and the public opinion to see if there would be some kind of negative spin all of the sudden, they would have been able to intervene and try to correct this public perception if all of the sudden the public would go negative on nanomaterials. S I don't know if, [Pause] It's really difficult to say. [Pause] You know, you should really talk to Mark Bächer. Mark Bächer was the person responsible for all the communications of the National Priority Research Program, which lasted something like 5 or 6 years, and he was really trying to get the message out. He had exhibits that were touring the country. [Pause] With great, easy to understand exhibits with hands-on experiments. Really to try to show people what nanomaterials—synthetic nanomaterials are and what they can be good for and all these things. He also organized a lot of public discussions and debates. He was following this question quite closely, what to do to the public aware but without getting people alarmed or afraid of nanomaterials. I'll send you his contact details; that might be an interesting person to talk to.

Appendix H: Transcription of the Interview with the Swiss Public

September 30, 2020 at 9 EDT

Rayna Harter interviewed a respondent to the initial public opinion survey with Marika Bogdanovich acting as secretary.

Rayna Harter (RH): Do you have any food allergies or dietary restrictions and if so what are they?
Participant 1 (P1): No, I can eat everything
RH: Have you ever heard of nanoparticles?
P1: Yes so I am now a PhD student in Fribourg, but before that in Physics, and before that I studied nanostructures technologies. So that is an applied Physics field that you get to know some nanoparticles. But honestly I have never heard about them in food basically. Not in my studies have really looked into it as well.
RH: What applications did you study specifically for nanoparticles?
P1: Well I heard a lot about applications in anmater research in solar cells. I also did an internship on vacuum insulation with nanoparticles. This I have also seen. Then there was a lot of, as I study physics, a lot of basic research of applications in solid state physics and I have also heard a little bit in medicine. So I have heard that magnetic nanoparticles can be applied for cancer therapy for example. This I also heard.
RH: Do you know what they are used for in food applications or do you have no idea?
P1: Not really honestly, I mean yah so nanoparticles are a little bit difficult because it is hard to define, because there are also living organisms are so small that you might call them nano. So I am not sure how to define it, because the bacteria and stuff can be considered as nanoparticles. But I am not sure what it is about or not.
RH: Okay so, just to give you a brief background of what nanoparticles are according to the definition, we are focusing our project specifically on nanoparticles that are specifically put into food to do some purpose. Whether that be increase the shelf life, make it look prettier,

or make it look less cloudy, things like that. Instead of the stuff that is just kind of would be in there like a milk or other colloid technically have nanoparticles that do not require labeling or stuff. It is very confusing because of that. We are focusing on stuff that is intentionally put into there to get some sort of result. So then from our survey we found that a lot of people listed microplastics. Have you ever heard of microplastics and if so what do you know about it?
P1: Yes, I have heard about microplastics that basically when a plastic gets smaller and smaller, but it always stays plastic. It just gets cutting into halves and halves and it is always getting smaller and it stays out there. And it is quite hard to get it out of the environment again. But that is about what I know about it.
RH: For the microplastics, have you seen microplastics in the media a lot or not in the general media or is it some general information you know? Where did you get this information?
P1: I think I have seen some documentaries about it yah. Probably I know it from that area.
RH: Are micro plastics mentioned in the media? Have you noticed them being mentioned a lot more than nanoparticles or the other way vice versa?
P1: Yes, I think microplastic is mentioned quite a lot. Nanoparticles especially in food I have not heard too much about. So yeah probably it is more about microplastics than nanoparticles.
RH: Have you ever when you bought a product or food from the store have you ever seen a label on the packaging proclaiming that it has nanoingredents in it. So in Swiss and European law it says that you have to have if it has a nano containing ingredient it has the ingredient then the word nano in brackets then the rest of the ingredients. Have you seen that ever?
P1: I don't think I've seen it. I am not sure if this is what companies advertise on there. Also I am not sure.
RH: Just the current laws in Switzerland and Europe mandate if you have a product that has nanoparticles specifically added into it. So say you are making a gum and you are going to put Silicon dioxide in there, oh no it would actually probable be titanium dioxide, you would put titanium dioxide in there to make it look whiter, and it is nanoparticle sized titanium dioxide, then you would have to put when you put titanium dioxide on an

ingredient list you would have to put a bracket. But it is really hard to find packages with those labels.

P1: Oh yeah, and you have to look for it on the packaging probably. So yeah I am usually am not reading the whole packaging so I mean I just do not see it.

RH: So here, we tried to find examples, but here in the US we don't have to so they don't.

P1: Okay

RH: So it is very difficult to get an example since were not in switzerland. If you saw a label on a food product that said it had nano containing ingredients, would that affect your willingness to purchase it.

P1: Well probably not, not too much at least. I mean I would probably wonder what it was about, but it certainly would not affect it in any positive or negative way.

RH: Okay. What is your opinion or impression of nanoparticles being added into food products?

P1: My opinion, I not sure if I know enough to form a solid opinion on it. So I um, so there are for sure some risks about it. I mean if you are working with nanoparticle sized powder you have to wear masks so it does not get into your lungs and stuff. So you have to be careful about it, but yeah I think there are ways to deal with it. So I am kind of undecided on that.

RH: Thank you so much and we have one more question. When did you learned about nanoparticles in general and then as well as when you learned about nanoparticles in food? Like when it was at all mentioned like location, what type of setting. If you remember, its okay if you don't.

P1: Yeah, so the problem is that it is a term that is used quite a lot, especially not in food, but in clothing to make it sound fancy or something. So I have heard about this for quite some time, probably even high school or something. In food, so when I heard about it was definitely much later. I don't know exactly when, but only recently.

Appendix I: Results of the Longform Survey

1. Do you have any food allergies or dietary restrictions, if so what are they?
    a. 2 responses for "None"
    b. 1 response for "Milk intolerance"
2. Have you ever heard of nanoparticles?
    a. 3 responses for "Yes"
3. Do you know what they are used for?
    a. 2 responses for "No"
    b. 1 response "as additive for colouring, packaging, anti-caking, for crisp/crunchy"
4. Have you ever heard of microplastic and what do you know about it?
    a. 1 response "Yes. I am not sure, but I think that microplastic can polluate the food. So when we are eating, particules of microplastic can go in our organism."
    b. 1 response "I heard about them in mechanical peeling cosmetics only."
    c. 1 response "Yes. They are microscopic plastic pieces that can be found into quite everything. They are disturbingly omnipresent, but I don't know if it was proved to be unhealthy - though plastic must obviously not be great…"
5. Have you seen nanoparticle labels on food packaging and do you know what it means?
    a. 1 response "No, I don't."
    b. 1 response "Among all E labelling as additives I never know which one is nanoparticles. I just look for 171 or 551"
    c. 1 response "No?"
6. If you saw that a product uses nanoparticles, would it influence your decision to purchase that food? Why or why not?
    a. 1 response "No, I dont think so. The provenance of the product is the only thing that can me drive to not buy a product. For example, if it was product in South America. But actually I don't watch the labels."
    b. 1 response "Yes it could help me to take a decision. Because I would not have to remember always what means the number and as they are controversial currently,

in case of doubt I prefer to be exposed less (potential risk reduced). I like to know what I am eating whether or not healthy."

c. 1 response "Yes. Despite not being a hardcore ecologist or so, I try to buy natural stuff."

7. What is your opinion or impression about nanoparticles in food products?
    a. 2 responses for "Partly Negative"
    b. 1 response for "Negative"
8. What is your reasoning for your opinion selected above?
    a. 1 response "I try to consume products that have been transformed as little as possible. That goes from "ready to eat" sauces or dishes, to this I guess."
    b. 1 response "Scientific papers, studies that are not influenced by lobbyists. News from media. Aseptic packaging is safe reason why I choose partly instead of totally negative. In my opinion fresher and healthier foodstuffs are raw food than refined food due to the duration before that I consume.I do not need much more extended shelf life."
    c. 1 response "Je pense que les nanoparticules peuvent rendre la nourriture plus saine."
9. Do you know where/when you learned about nanoparticles?
    a. 1 response "In the newspaper."
    b. 1 response "at school, I mean much more at university"
    c. 1 response "I haven't. From what I understand in this survey, what I thought to be nanoparticles were for instance microscopic plastic pieces as described above, but it also seems to be some kind of food technology made to "improve" it, help to preserve it longer or so. I haven't heard of the latter at all."