# Nanotechnology in Food Packaging: A Qualitative Study on Creating Consumer Awareness through Effective Communication

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Master Thesis Communication Science

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## Preface

You are reading my master thesis: *Nanotechnology in Food Packaging: A Qualitative Study on Creating Consumer Awareness through Effective Communication.* This thesis was written as the final requirement for completing the master's program in Communication Science at the University of Twente.

My interest in this topic arises from a personal commitment to contributing to society, particularly by addressing the urgent issue of food waste. It is concerning that, while many people around the world lack access to sufficient food, huge amounts are still discarded every day. I believe solving this paradox is both a moral imperative and a technological challenge. That is why I am inspired by the potential of nanotechnology, a field with the power to transform multiple industries. Food packaging impacts us all daily, and its potential to reduce food waste motivated me to explore how nanotechnology can provide solutions for a sustainable future, particularly through effective communication strategies that raise public awareness and understanding.

I could not have completed this thesis without support, and I would like to express my gratitude. First, I want to thank all the participants and experts who contributed to this research. Second, I would like to thank my second supervisor, Thomas van Rompay, for his valuable feedback. Finally, I would like to extend a special thanks to my first supervisor, Joyce Karreman, who provided insightful advice, discussions, and encouragement to help me complete this thesis.

With this thesis, I hope to contribute to raising public awareness about nanotechnology in food packaging to address food waste.

I hope you enjoy reading it — Mart Janssen

## Abstract

***Background:*** Nanotechnology is becoming increasingly important in food packaging, offering solutions that extend shelf life, improve safety, and enhance food quality and traceability. Despite its potential to reduce the one-third of global food wasted, and approximately 25% in the Netherlands, public awareness remains limited. This lack of consumer knowledge is a key barrier to adoption. While previous studies have examined public opinions, this study focuses on how to create awareness of nanotechnology in food packaging to address food waste. ***Methods:*** This qualitative study involved four semi-structured focus groups with eco-conscious and non-eco-conscious consumers, as well as two semi-structured interviews with three experts in nanotechnology and food packaging. ***Results***: Participants had limited knowledge of nanotechnology in food packaging and often confused it with unrelated fields. While benefits like reduced food waste were seen, trust concerns remained. Preferred information channels differed by age, but trust was highest in independent institutions like universities and public media. Visual tools such as QR codes on packages were favored for delivering deeper, non-commercial information. Experts proposed a three-step model: scientists introduce the technology, manufacturers communicate transparently, and consumers access information via trusted platforms. ***Conclusion***: Clear, assessable, and tailored science communication is important for bridging the knowledge gap around nanotechnology in food packaging. By addressing trust, perceived risks, and audience needs, such communication shapes public attitudes and behavioral intentions. When framed around practical benefits like food waste reduction, it supports acceptance and enables informed, socially responsible choices at the intersection of innovation, policy, and everyday consumption.


*Keywords:* public awareness, nanotechnology, food packaging, science communication, waste

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# 1. Introduction

One of the most significant challenges facing the food industry is food waste. According to the World Economic Forum, approximately one-third of all food produced globally is either lost or wasted (Newton, 2023). This amounts to about 127 kilograms per person (Europese Commissie, 2022), leading to more than a global economic loss of $1 trillion each year (Newton, 2023). In the Netherlands, about 25% of all food is wasted, with serious consequences for the climate and environment. Reducing it preserves food, cuts costs for farmers, businesses, and consumers, and reduces environmental harm from food production and consumption (Europese Commissie, 2022). Consequently, the United Nations (UN) aims to reduce global food waste by 50% by 2030. Similarly, both the European Union (EU) and the Netherlands have committed to halving food waste (Rijksoverheid, 2010).

To combat food waste, the national government encourages consumers to reduce waste through tips from nutrition centers (Rijksoverheid, 2010). The "Together Against Food Waste" foundation also offers advice, and every September marks “Waste Free Week,” where consumers and companies can participate for free. Additionally, initiatives like the "Too Good To Go" box and food donations to organizations like the food bank help reduce waste (Lawson, 2025). An emerging new solution to this issue is nanotechnology in food packaging (Newton, 2023). Nanotechnology, also referred to as nano packaging, involves producing and manipulating nano-sized materials – less than 100 nm in diameter, with 1 nm being one millionth of a millimeter – that contain novel properties (Ramachandraiah et al., 2014; Weiss et al., 2006). It protects its contents from any damage that could happen during transport, handling and storage. Also, it improves barrier properties, thermal stability, strength and durability of packaging materials, helping extend the shelf life of food products (Ashfaq et al., 2022).

Although nano packaging is widely acknowledged for its potential in the food sector, its commercial adoption remains limited. In the US, for example, some PET bottles used for beer and flavored alcoholic drinks are made with a special type of plastic (barrier nylon resins) that includes nylon 6 nanoclay composites. This material helps prevent oxygen from getting inside the bottle, keeping the drinks fresher for longer. Or in New Zealand, sensor stickers are used to indicate the freshness of fruit by changing color in reaction to aromatic molecules (Adeyemi & Fawole, 2023). These examples demonstrate that nanotechnology is already being applied in food packaging, but broader adoption is limited due to several challenges.

One of the main challenges is public awareness. Despite research by Cobb and Macoubrie (2004), Hart (2007), Kahan et al. (2007), and Pérez-Esteve et al. (2022), which consistently demonstrated the ongoing lack of public knowledge regarding nanotechnology in food packaging, there has been only a slight improvement in awareness over time. Many consumers still report knowing little to nothing about nanotechnology in food packaging. Even with this lack of understanding, consumer opinions about nano-packaging are often shaped by perceived benefits, such as enhanced sustainability, quality, and hygiene. While most consumers remain neutral or even positive towards nano-packaging, underlying mistrust persists. This indicates that the acceptance of nano-packaging may be achievable if its functional benefits are effectively communicated and demonstrated.

Another significant barrier to the widespread adoption of nanotechnology in food packaging is food technology neophobia (FTN), defined as the aversion to new food technologies. FTN blocks dietary change and contributes to the high failure rates in the adoption of food innovations (Chen, 2018; Chen et al., 2013; Nucci & Hallman, 2015; Cattaneo et al., 2018; Egolf et al., 2019). Many consumers view these technologies as risky and tend to prefer

"natural" or less processed products (Martins et al., 2019). As a protective psychological mechanism, neophobia categorizes unfamiliar innovations as potentially dangerous (Greenberg & Mettke-hofmann, 2001). Globally, the FTN score has been measured at 46.4, indicating a neutral position overall.

Regulation also plays a critical role in the adoption of nanotechnology. Agencies such as the U.S. Food and Drug Administration (FDA), Institute of Food and Agricultural Sciences (IFAS), and U.S. Environmental Protection Agency (USEPA) have begun to address the potential risks of nanoparticles, particularly concerning toxicity and bioaccumulation. These regulation considerations have resulted in tighter controls, which in turn delay market entry. According to He et al. (2019), legislation is essential not only for regulating product marketing but also for ensuring responsible disposal of food packaging—two aspects that are still insufficiently developed worldwide.

Although the fact that nanoparticles are used widely in many everyday products, research shows that customers are most of the time unaware of their existence, especially when it comes to food packaging. This presents another difficulty. Both adoption and acceptance are limited by this lack of knowledge. As a result, educating the public on the advantages, dangers, and uses of nanotechnology is crucial to influencing opinion and building trust. Building educated, focused communication strategies is crucial to filling up current knowledge gaps and promoting the broad use of food packaging enhanced by nanotechnology (Siddiqui et al., 2022). For this reason, this study's proposed research question is:

**RQ:** “How can we raise public awareness of nanotechnology in food packaging to reduce food waste?”

This study advances our understanding of science and its relevance to society. From a scientific standpoint, it offers information on how to effectively communicate new, sustainability-driven technology. In addition to highlighting factors impacting public acceptance or resistance, the research contributes to science communication by investigating strategies to increase knowledge, reduce neophobia around food technology, and build trust. Future multidisciplinary research on public engagement with innovation outside of the food industry may benefit from these findings. From a societal perspective, nano packaging presents a possible answer to food shortages and sustainability goals. By extending shelf life, it could reduce the impact on the world's food supplies and waste in developed nations. Informed consumers are more likely to embrace these changes, making public education essential (Mahmud et al., 2022). Without sufficient knowledge, resistance may limit adoption despite the benefits for the environment and society (Chen et al., 2013).

By aligning with sustainability objectives, such as reducing waste and improving resource use, this research can guide policymakers, producers, and educators in developing targeted awareness strategies. Ultimately, the study emphasizes the need for early public engagement to ensure acceptance and unlock the full societal value of nanotechnology in transforming food packaging systems.

By examining how communication could impact attitudes, increase understanding, and direct consumer behavior about nanotechnology in food packaging, this study contributes to scientific communication. In addition to functional advantages, the widespread acceptance of such technologies also depends on information sources' reliability, clarity, and trustworthiness. Focus groups and expert interviews serve as tools in a qualitative approach to investigate these processes. To create successful, audience-centered awareness strategies that support responsible

adoption and sustainability goals, it is essential to gain a deeper understanding of public knowledge, risk and benefit perceptions, neophobia levels, trust in communication providers, and media preferences.

# 1. Literature review

## 2.1 Food waste

The United Nations estimates that 795 million people live without food and that around 1 billion people are undernourished because of the annual loss of 1.3 billion tons of food (Grosso & Falasconi, 2018). Due to a lack of resources and a lack of urgency to address the issue, food waste has become worse. The issue is expected to persist until 2050 as demand for natural resources such as energy, land, and water increases. Food waste is becoming more widely acknowledged as a major global sustainability issue because of both national and international efforts. The Sustainable Development Goals (SDGs) provide as a framework for solutions, while mitigation attempts relate food waste to associated problems including food poverty. SDG 2 aims to stop hunger, while SDG 12 focuses on sustainable patterns of production and consumption (Manzoor et al., 2024).

Food waste and loss have serious negative impacts, drawing increasing global attention due to their links to food security and climate change. It directly affects the economy, the environment, and society, resulting in the loss of the edible foods prepared for human consumption (Papargyropoulou et al., 2014). Also, food waste occurs across the entire food supply chain, from the initial stages of manufacturing to final consumption. The lack of efficient physical infrastructure and post-harvest, production, packaging and processing techniques, causes food loss in its early stages (Chaboud & Daviron, 2017).

To support efforts aimed at reducing food waste, the government funds research into strategies to combat it and monitors annual waste levels in the Netherlands (Rijksoverheid,

2010). A promising solution is nano packaging, which uses nanotechnology to develop advanced food packaging materials, substantially reducing spoilage (Singh et al., 2017).

**2.2 Technologies and public perception in general**

While the term 'technology' is well known, it is loaded with a wide range of interpretations and underlying assumptions. It goes beyond digital devices and historically includes tools like the typewriter or early irrigation systems—technologies once considered transformative for civilization. A precise yet flexible definition is given as “a system created by humans that uses knowledge and organization to produce objects and techniques for the attainment of specific goals.” The roots of the word lie in terms like the Greek *tekne*, meaning “art,” “craft,” or “skill,” and the Latin *texere*, meaning “to weave” (Volti & Croissant, 2024).

Despite its potential, today’s technology leaves us both exhilarated and terrified (Vuleta, 2020). Miracles such as gene therapy and interstellar spacecraft coexist with the dangers of global climate change, overpopulation, and the threat of nuclear annihilation. Technology also produces social disruptions, including job loss due to automation or data breaches that disrupt security and lead to financial losses (National Science Foundation, 2014). Public opinion remains favorable overall, though many technologies are held in high esteem while specific technologies sometimes generate significant criticism. Ultimately, affirmation of technology is based more on faith than on understanding, and most people remain “poorly informed consumers,” unable to grasp the broader consequences of the rapid technological change around them.

Consumers’ role in accepting any technology depends on the safety of the technology used. In the present digitization era, people are more concerned about the food products that are

promoting their health, but they are equally interested in the technologies which do not cause any harm to health and environment. Among the social factors, social concerns, norms and media play an important role. In addition to the social factors, there are psychological aspects such as awareness, motivation, attitude, beliefs, fear, and inherent habits which drive consumers to use new technology (Siddiqui et al., 2022).

Innovative food technology is typically viewed by the public with hesitancy, uneasiness, doubt, and at times complete skepticism. Young (2003) argued that the decades-long resistance to canned food is proof that the public has always been skeptical of new food technologies. Not only is food viewed in terms of its practical uses, but it is also intricately linked to a wider social and psychological framework. In addition to deeply ingrained beliefs and basic worldviews, this framework encompasses attitudes toward science, the environment, and health. Furthermore, how we view, and handle food is greatly influenced by our family and personal routines.

Furthermore, Pidgeon et al. (2005) note that while research shows generally negative opinions, most individuals do not prioritize novel food technologies, and early interest in the topic is often minimal. This does not imply that the public is uninterested in the discussion, either, as most individuals will express an opinion when asked. Novel food technology is often not well known. For instance, the term "nanotechnology" is unfamiliar to many UK customers.

Furthermore, opinions in the USA appear to be generally more favorable than those in Europe regarding most of the technologies examined. This is explained by several factors, such as Americans' greater faith in their regulatory bodies and their more positive views of science and technology. Customers in developing nations and Asia also have more favorable opinions about new food technology, suggesting that these regions will profit from them more. Public perception, which is influenced by historical skepticism, a lack of information, and a larger

cultural context, keeps shifting between optimism and uneasiness despite the revolutionary potential of (food)technology (Hoban, 2004; Chen & Li, 2007).

**2.3 What is nanotechnology?**

The term "nanotechnology," or "nanotech," comes from the Greek word "nano," which means "billionth," and refers to technology that works with items smaller than 100 nanometers (nm) (Ghazi et al. 2018; Wang et al. 2017; Ghaffari et al. 2012; Gleiter 2009; Bhushan 2016; Nouailhat 2010). Structures with at least one dimension of 100 nm or fewer are its main emphasis (Baer et al., 2003; Whitesides, 2005). From the food we eat to the clothing we wear, nanotechnology has a wide range of uses in both industrial and everyday settings (Thakur, 2022).

The size, shape, and dimensions of nanoparticles differ a lot. Their enhanced mechanical strength, increased reactivity or stability, and bigger surface-to-volume ratio give them unique features above their bulk counterparts (Sui et al., 1996). They can be categorized as one-, two-, three-, or zero-dimensional. Nanodots and other zero-dimensional forms have fixed height, width, and length. Carbon nanotubes are one-dimensional, whereas graphene and other two-dimensional materials are long and wide. All three dimensions are present at the nanoscale in three-dimensional nanoparticles, like gold particles. They might be flat, tubular, spherical, or cylindrical in shape and structure, and their surface characteristics can be consistent or diverse (Rashad et al., 2009).

Nanostructures can be made from different materials that fall into one of three categories: organic, inorganic, or hybrid (Yu et al., 2018). By increasing strength, barrier qualities, and antibacterial activity, organic nanoparticles improve food packaging while promoting sustainability (Jaiswal et al., 2024). Whey proteins, lipid-based nanoparticles, and chitosan are a

few examples (Rhim et al., 2013; Pirsa et al., 2022). Inorganic nanoparticles improve shelf life and provide antibacterial protection. While titanium, zinc oxides, and silicon dioxide limit oxygen and moisture, silver reduces microbiological development, enhance sustainability and preservation (Shah et al., 2022; Yu et al., 2018). These advancements reduce waste and promote environmentally friendly food packaging.

### 2.3.1 Applications and current practices of nanotechnology in food packaging

Nanotechnology is applied in food packaging in three different ways: improved properties (IP), active packaging (AP), and smart packaging (SP). Each method is characterized by specific materials combined with nanomaterials (see Appendix J). By exploring these three packaging approaches, it is possible to clearly observe the applications of nanotechnology in this area. These three methods are explored in more detail below.

IP focuses on making packaging stronger, more heat-resistant, and better at blocking moisture and gases (Kuswandi & Moradi, 2019). For example, some yoghurt packaging is made stronger without adding more plastic. It can also help keep things like salads fresh by improving the packaging's ability to block oxygen and water (Statnano, 2018). These changes help make both traditional and sustainable packaging methods better (Fortunati et al., 2012). The second technique, AP, focusses on keeping food fresh. It does this by either releasing chemicals that kill bacteria and mold or by absorbing harmful gases like oxygen and ethylene, which cause food to spoil. For instance, some lunchboxes in the UK contain tiny silver particles to prevent the growth of bacteria and microbes, extending the freshness and safety of the food (Statnano, 2016). The third technique, SP, allows the monitoring of food quality using nano sensors that respond to changes in the environment by acting as labels, colors, or coatings. To indicate changes in the

state of the food, these sensors change visual characteristics like color. By providing customers with real-time feedback, SP creates increased transparency and trust (Enescu et al., 2019).

Nanotechnology improves environmental sustainability in addition to preservation and safety. Lightweight nanostructured packaging uses fewer raw materials and is more environmentally friendly. Additionally, more sustainable packaging techniques are supported by improved recyclability (Aswathi et al., 2022). Although these benefits, the use of nanotechnology in food packaging is still in its early stages. While functional nanoparticles are being used more to increase safety and shelf life (Barage et al., 2022), their commercial acceptance is still quite limited.

Current practices show that nanomaterials are already present in commercially available packaging. For example, Honeywell International Inc. uses nylon 6 nanoclay composites in barrier nylon resins for PET bottles to prevent oxygen absorption in beer and flavored beverages. Similarly, RipeSenseTM from New Zealand developed a sensor sticker that changes color based on aromatic compounds to indicate fruit freshness. In Japan, cerium oxide is used in films to protect meat and fish products from oxygen exposure (Adeyemi & Fawole, 2023). Additional examples of nano-based food packaging materials can be found in Appendix G. These global developments indicate progress; however, commercial use in Europe remains limited. This is largely due to strict regulatory frameworks and legal uncertainties (Maria et al., 2024), which will be further examined in the following section.

### 2.3.2 Regulations and legislations

Guidelines from regulatory bodies provide secure pathways for manufacturers, importers, and consumers to ensure the safety of food products in the market (Tarhan, 2020). However, the

safety of nanotechnology packaging is a complex topic, since there are concerns that nanostructures can be toxic to humans and the environment. Despite these risks, there is still a lack of established regulations for nanotechnology applications globally. This is largely due to insufficient comprehensive research on the safety assessment and migration properties of nanomaterials from packaging into the food system (Huang et al., 2018).

Because of worries regarding possible toxicity, the use of nanoparticles in food contact materials is illegal in some nations but allowed in others (Adeyeye & Ashaolu, 2021). The Food and Drug Administration (FDA) in the US controls packaging containing nanotechnology that encounters food. The FDA requires pre-market approval from manufacturers via the Food Contact Notification (FCN) system or a Food Additive Petition (FAP). Nevertheless, this pre-market permission requirement does not apply to substances that are categorized as generally recognized as safe (GRAS). Additionally, companies that publish a scientific risk assessment in a peer-reviewed publication are allowed to sell their products without first obtaining FDA permission (del Rosario Herrera-Rivera et al., 2024).

On the other hand, EU regulations are more extensive than US regulations. Under regulation EC 1935/2004, the EU oversees regulating packaging materials, including nanomaterials. If nanoparticles aren't harmful to human health, this rule allows their use in food packaging. Additionally, in line with the Novel Food Regulation EC 258/97, packaging containing nanoparticles must be assessed prior to being put on the market. Under EEC Regulation 89/109, nanomaterials must likewise be regulated, even if they have already received bulk authorization. A functional barrier needs to ensure a maximum migration limit of 0.01 mg/kg in the case that illegal substances are used (del Rosario Herrera-Rivera et al., 2024).

As can be seen, there is a growing interest and emerging applications, while the regulatory landscape for nanotechnology in food packaging remains fragmented and underdeveloped. Safety continues to be a central concern: the potential toxicity, bioaccumulation, and migration of nanoparticles into food still raise significant questions. Although regulatory agencies like the FDA and EU have taken important steps, global consistency and scientific consensus are still lacking (He et al., 2019). To ensure safe innovation and build consumer trust, further independent and long-term research is essential to clarify risks, validate benefits, and guide future legislation in a responsible and transparent manner (Mitrano & Wohlleben, 2020; Bumbudsanpharoke & Ko, 2015; Amenta et al., 2015).

## 2.4 Public perception of nanotechnology in food packaging

Public perceptions of new and emerging technologies have significant implications for future policies regarding those technologies. Since public perception defines people's attitudes toward nanotechnology and determines whether they embrace or reject its products, it is essential to understand how people view the risks and benefits of nanotechnology (Binder et al., 2011; Satterfield et al., 2012). This chapter will also look at the public's awareness, neophobia, trust, and familiarity with online communication providers in addition to these issues.

### 2.4.1 The public’s knowledge level

Public awareness and acceptance play a crucial role. Although nanotechnology presents innovative solutions, insufficient consumer knowledge creates significant barriers to its implementation. Therefore, despite its potential, consumer unawareness remains a significant barrier to the widespread acceptance of nano-based food packaging. Most of the time, public awareness is overlooked, as government agencies and manufacturers serve as the primary sources of information, rather than independent scientific organizations or consumer education

initiatives. This lack of transparency contributes to consumer skepticism and resistance among the public (He et al., 2019).

A case study in Singapore by George et al. (2014) demonstrated that a lack of awareness directly correlates with negative public perception, as seen in a survey of 1,080 individuals over the age of 15. Even agri-food organizations, which play a key role in the food industry, show low awareness regarding nanotechnology, as revealed in an Irish survey by Handford et al. (2015). In this study, 14 agri-food stakeholders were interviewed, and 88 others responded to an online questionnaire, indicating that limited access to information and resources in combination with low awareness remains a critical barrier to understanding nanotechnology applications in food packaging (Handford et al., 2015).

In more recent research, Gómez-Llorente et al. (2022) measured that before giving information about nanotechnology and showing food packages in which this had been employed, the participants were asked about their knowledge on this new technology. Most participants expressed that they knew “something” or “little” (38.8% and 12.2% respectively) about this technology, while a lower percentage knew “nothing” or “a lot” (16.3% and 12.2%, respectively). Therefore, consumer unawareness remains a significant barrier to the widespread acceptance of nano-based food packaging.

### 2.4.2 The public’s neophobia level

Food technology neophobia (FTN), an aversion to new food technologies, block dietary change and contributes to the high failure rates in adopting new processing technologies (Chen, 2018; Chen et al., 2013; Nucci & Hallman, 2015; Cattaneo et al., 2018; Egolf et al., 2019). Many consumers view new technologies as risky and prefer "natural" and less processed products

(Martins et al., 2019). Moreover, neophobia serves as a protective mechanism, categorizing unfamiliar innovations as dangerous (Greenberg & Mettke-hofmann, 2001).

Knowing the degree of neophobia is essential for raising consumer knowledge of nano packaging because it helps identify consumer resistance and concerns and enables specific strategies to highlight benefits and resolve potential risks (Chen, 2018; Martins et al., 2019). With a range of 18 to 90, the neophobia level in the study by Pérez-Esteve et al. (2022) was 51.10, which is somewhat below the central value of 52 (neutral). These results indicate a medium neophobia level for the Spanish population and significant variability, thus suggesting consumer groups with different levels. These FNTS values were slightly higher than recent studies in the USA or global values of 44.22 and 46.4 (Garrido et al., 2021; Kuang et al., 2020). In Brazil, these global values were 46.2 (Coutinho et al., 2021). However, higher values were observed in Australia, Canada, and Italy, with global values of 54, 59 and 61, respectively (Evans et al., 2010; Matin et al., 2012; Verneau et al., 2014).

Furthermore, in the research of Gómez-Llorente et al. (2022) is also the neophobia level measured. A score of 4.0 was obtained as the mean value (minimum and maximum value of 3.3 and 4.7, respectively). Considering that a score of 4 is a neutral position in terms of neophobia to new food technologies. These results underline that neophobia varies across countries. Still, many consumers maintain a reserved or neutral attitude toward new food technologies. This must be taken into account when introducing innovations such as nano packaging.

### 2.4.3 The public's perceived benefits & risks

Further, while nano packaging offers numerous benefits, consumers may respond differently. For instance, experts often question why consumers accept relatively high risks but

reject risks they perceive as low (Siegrist et al., 2007). In the study by Li et al. (2020) involving 638 consumers in China, smart packaging was accepted by 56% of participants, while 44% did not. Additionally, Chen et al. (2013) found that individuals in Taiwan who perceive more benefits from nano packaging tend to have a more favorable opinion, whereas a greater 12 attitudes perception of risk leads to negative. Also, Siegrist et al. (2007) noted that consumer acceptance improves with increased knowledge and trust in companies producing nano-packaged foods. While it provides numerous advantages, opinions on its acceptance keep divided.

Therefore, it is important to explore consumer-perceived risks. Research from Pérez-Esteve et al. (2022) indicated that respondents' positions were neutral for all risk-related items and disagreed that new technologies are unnecessary or enable better control of choices or diets. Although higher scores were given to statements like "new foods are no healthier than traditional ones", and "society should not depend heavily on technologies to solve its food problems". Also, consumers distrust media's perception of new food technologies, aligning with studies showing low trust in media-provided information (Capon et al., 2015; Erdem., 2018).

Moreover, consumers face several practical and psychological concerns when considering products that use smart and active packaging technologies. According to Young et al. (2020), various barriers constrain purchasing products using active and intelligent/mart packaging technologies. These include concerns about additional costs, as noted by Greehy et al. (2011), Aday and Yener (2015), and Spence et al. (2018). Other consumers worry about potential risks, such as whether the packaging functions as advertised (Aday and Yener, 2015), contains harmful components (O'Callaghan and Kerry, 2016), or increases food waste (Pennanen et al., 2014). Accessibility concerns include color-based indicators being ineffective for color-

blind consumers (Pennanen et al., 2014) and requiring changes to purchasing habits (Lindqvist et al., 2011).

Additionally, a household mail survey conducted in the continental US by Berube et al. (2011) found that people were optimistic about nanotechnology development despite the risks. Similarly, Brazilians saw nanotechnology with a profound sense of optimism providing solutions to environmental and social problems in a recent study comparing public responses towards nanotechnology in the UK and Brazil (Macnaghten & Guivant, 2020). These concerns, together with the perceived advantages, demonstrate that consumer attitudes are shaped by a complex balance between potential risks and expected benefits.

### 2.4.4 The role of familiarity and trust in consumer attitudes

In addition, key elements influencing consumer acceptability include familiarity with nano-based packaging technologies, perceptions of risk, and trust in the organizations that developed them. According to Young et al. (2020), the most important factor is a lack of awareness or information about active and intelligent packaging using nano packaging. Furthermore, studies by Capon et al. (2015) demonstrate that more knowledge and familiarity with food packaging nanotechnology resulted in a decrease in perceived risk and an increased number of favorable perceptions. Furthermore, people who are younger, more educated, and employed in the agri-food industry are less likely to be neophobic. In contrast, Young et al. (2020) found familiarity unrelated to age but lowest among women and less educated consumers, highlighting socio-demographic influences. Similarly, Viscecchia et al. (2018) reported that higher consumer education relates with lower perceived risk a greater willingness to purchase nanotechnology- based packages.

Familiarity with intelligent packaging was reported by only 17% of respondents, while just 4% were familiar with active packaging (Young et al., 2020). This low awareness may stem from general consumer indifference toward packaging, as many failed to recognize examples encountered in the market. Erika et al. (2018) and Erdem (2014) observed that this lack of knowledge hinders consumers from forming opinions about the benefits and risks of these technologies. Additionally, there is a widespread misunderstanding of food production technologies, including the role of protective bacteria (Van Wezemael et al., 2011), and food safety risks (Vandermoere et al., 2009). This unfamiliarity with packaging technologies remained consistent regardless of respondents' research on the topic.

The second most important moderating variable was trust, including trust in the supply chain, brand trust (Aday and Yener, 2015), trust in regulatory agencies (Stampfli et al., 2010; Aday and Yener, 2015; Erdem, 2014), and general societal trust (Greehy et al., 2011; Spence et al., 2018). Spence et al. (2018) suggested that trust in government bodies fosters trust in the overall system and technology. They proposed a feedback loop between the information provided by intelligent packaging and supply chain trust. Another study found that some consumers required a seal of approval from governmental agencies for product acceptance (Aday and Yener, 2015). Finally, trust was identified as a significant predictor of acceptance (Spence et al., 2018). Together, familiarity and trust form essential foundations for public acceptance of nano-based packaging and should be central in shaping communication strategies and policy decisions.

Observing the literature, consumer awareness of nanotechnology in food packaging remained low, largely due to insufficient public education and a lack of transparency from trusted institutions. Perceptions were shaped by both perceived benefits, such as shelf-life

extension and sustainability, and concerns about unfamiliarity, cost, and safety. While neophobia varied by region, many consumers held neutral or hesitant attitudes toward new food technologies. Familiarity with the technology and trust in producers and regulatory bodies seriously influenced public opinion. Higher awareness and education levels correlated with reduced perceived risk and greater willingness to adopt nano-based packaging. Still, adoption faced barriers such as uncertainty, mistrust, and a lack of perceived necessity. The upcoming focus groups and interviews will further examine these above dynamics and explore how communication strategies can increase public understanding and support for nano-based food packaging.

# 2. Method

## 3.1 Research design

A qualitative research design is used in this study to investigate how experts and consumers view nanotechnology in food packaging. This method works well for revealing complex information on neophobia, perceived risks and advantages, knowledge levels, trust in information sources, and preferred communication techniques. Expert reflection and participant involvement were combined through semi-structured consumer focus groups and expert interviews. While focus groups facilitate lively debate and record shared concerns, interviews offer important viewpoints from the domains of food packaging and nanotechnology. This approach supports the development of successful awareness methods (Pathak et al., 2013; Corbin & Strauss, 2014) and allows for a more thorough understanding of subjective experiences by finding a balance between structure and flexibility (Ryan et al., 2013). Expert feedback on the group findings allows for fine-tuning the recommendations where needed.

## 3.2 Context and sample

Ethical approval was requested and obtained from the BMS Ethics Committee of the University of Twente to ensure participants welfare and data confidentiality (See Appendix A). Further, to address the research question, purposive sampling was employed, a method that is widely used in qualitative research. This technique is designed to identify cases that are particularly informative, thereby ensuring the optimal use of available resources (Patton, 2014). To gain insight into the phenomenon under study, the sample for the focus groups consisted of individuals who were not consciously interested in sustainability but also with individuals who actively conscious care about sustainability. The sample for the in-depth interviews consisted of experts in related fields of nanotechnology and (food)packaging industries. The participants

were either personally approached or responded to a LinkedIn message, indicating their willingness to take part in the study and fulfilling the requirements (See appendix D).

Four focus groups were conducted: three with consumers who do not consciously care about sustainability and one with consumers who do consciously care about sustainability. In addition, a total of two interviews were held with three experts. During these focus groups, participants were assessed on their knowledge of nanotechnology, their perceptions of its risks and benefits, their preferred communication channels, their level of neophobia, their trust in communication providers, and their willingness to purchase nano packaged food. Furthermore, the results from the focus groups were presented to the experts, who were then asked to share their professional opinions to determine whether the insights derived from these focus groups are realistic and justified from their perspective. This approach enabled comprehensive and reliable conclusions to be drawn about how can we raise public awareness of nanotechnology in food packaging to reduce food waste.

The final sample consisted for the focus group included 22 participants, consisting of seventeen participants who do not consciously care about sustainability, and five who do. Among the participants, there were seven men and fifteen women, representing a diverse age range of 19 to 59, as well as various work sectors. In addition, the three participants who were interviewed were two men and one woman, aged between 29 and 60, who work in various industries of nanotechnology and (food)packaging industries. This diverse sample strengthens the study's ability to identify patterns and differences in obtaining information about nanotechnology. Ensuring that the findings become more robust and relevant to a wide range of audiences and in the end contribute to a more effective communication and awareness strategy.

### 3.3 Data collection

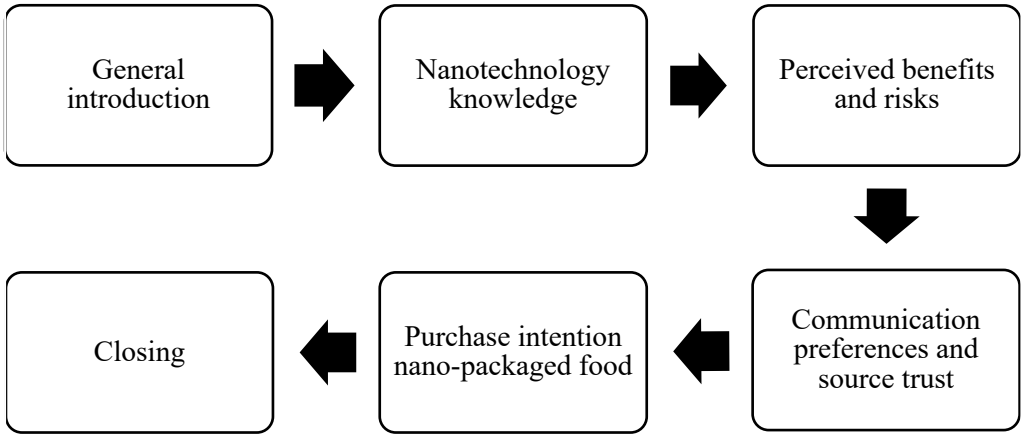
An informed consent process was conducted with participants, outlining the study's objectives, their rights, and the measures taken to protect their personal information (See Appendix E). The data was stored in a personal, secure network folder at the University of Twente. On average, focus groups lasted about one hour and 24 minutes, while interviews averaged 58 minutes.

#### 3.3.1 Focus group protocol

The focus groups were organized in a structured system to ensure systematic data collection, as illustrated in Figure 1.

**Figure 1.**

*Components of the focus group protocol*




In part 1 of the focus group, participants were asked general questions about their work, daily routines, and personal background. Questions such as, *"Can you tell me who you are, where you come from and what kind of work you do?"* were used to get to know each other better. This helped create a comfortable atmosphere (Patton, 2014).

In the focus group, the core section begins with part 2, where participants were asked about their knowledge level regarding nanotechnology. To measure their general attitude toward new technologies beforehand, they were asked, *"On a scale of 1-10 how positive do you feel about new technologies?".* Additionally, the questions *"What do you know about nanotechnology in general"* and *"What do you know about nanotechnology in food packaging?"* were asked. On top of those, participants were also asked *"Where have you received this information?"*. These questions were relevant because they assessed participants' knowledge levels while also providing insights into how individuals acquire information about such technologies.

Part 2 is followed by participants' perceived benefits and risks about nanotechnology in food packaging, which forms part 3. This part started with the instruction for participants to write down the benefits they perceive on a green post it, and the risks or concerns they associate on a red post it. To measure the neophobia level, the question *"How comfortable are you with the use of new technologies in food production and packaging?"* was asked. This question used a scale where 1 stood for "very uncomfortable" and 10 for "very comfortable." This approach allowed participants to reflect on their perceived benefits and risks first, as the writing activity gave them more time to think about their answers. In addition, they could rate how comfortable they are with new technologies related to food production and packaging.

Following the section on benefits, risks, and levels of neophobia, part 4 started, which focused on preferred communication channels and trust in sources. Participants were asked questions like, *"How do you currently receive information about new technologies?"* and *"Who do you trust to provide accurate information about nano packaging?"*. These questions aimed to reveal both the communication channels participants use to gather information about new

technologies and the channels they consider trustworthy. To provide the provision of information, participants were asked follow-up questions such as, *"Where would you prefer to receive information about nano packaging?"* and *"How would you prefer to receive information about nano packaging?"*. By following up on their reasons for these preferences, it was possible to gain valuable insights.

Part 5, the final section of the core study, focuses on participants' intentions to buy food that has been nano packaged. Participants were asked to rate their likelihood of purchasing a product that uses nanotechnology in its packaging in this section. Students answered on a scale of 1 to 10, with 1 indicating "very unlikely" and 10 indicating "very likely." Participants were also asked to provide an explanation for their ratings to have a deeper understanding. They were also questioned if they would be prepared to pay more for food that was packed with nanotechnology. The focus group's last part (part 6) appreciated everyone for their time and answers throughout the discussion.

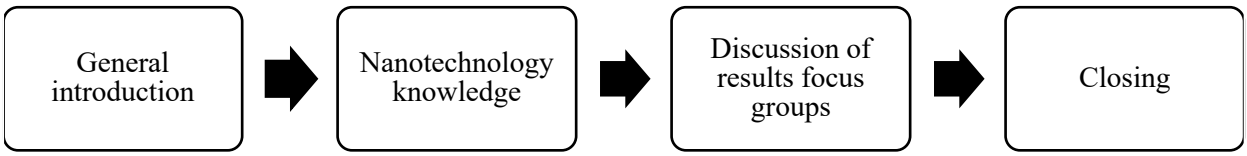
The structure of this interview was chosen so that participants were able to share opinions in a confident atmosphere and open themselves up to others' opinions as well. This successful approach ensures that the focus groups are both thorough and consider different opinions of the participants while providing rich data for analysis.

### 3.3.2 Interview protocol

The interviews with experts were organized in a structured system to ensure systematic data collection, as illustrated in Figure 2.

**Figure 2.**

*Components of the interview protocol*




The structure of the interviews was thoughtfully designed to offer a comprehensive and flexible approach for exploring ways to raise public awareness about the use of nanotechnology in food packaging. Additionally, the format created enough opportunity for experts to share their perspectives on creating awareness of nanotechnology in packaging and on informing the public about this topic.

In part 1 of the focus group, participants were asked general questions about their work, daily routines, and personal background. Questions such as, *"Can you tell me who you are, where you come from and what kind of work you do?"* were used to get to know each other better. This helped create a comfortable atmosphere (Patton, 2014).

After that, the core session (part 2) started. In this part the experts were asked questions like, *"How do you feel about new technologies?"* and *"What do you know about nanotechnology in food packaging?"*. Furthermore, the experts were requested to specify how they acquire this information and knowledge, allowing for a deeper understanding of their information-gathering processes as experts.

In part 3, the discussion started about the results of the focus groups. The experts were in the first instance briefed on the topic, for example regarding "attitudes toward new technology in general." Following this, they were presented with the results of the focus group discussions. This led to a series of questions, such as *"Do you recognize this image, or do you perceive a*

*different sentiment in your practice?"* and *"What do you think is necessary to alleviate these doubts or fears?"*. The discussion also explored how communication could be improved, with questions like *"Which of these concerns do you personally find most valid or understandable, and which do you believe should be prioritized in communication, and why?"*. Additionally, the experts were asked, *"How can we help consumers gain confidence in nanotechnology in packaging?"*. By engaging with the experts in this way, it was able to understand their reactions to the findings of the focus group while also gaining insights into how best to raise awareness about nanotechnology in food packaging among the public. The final section (part 4) ended the interview by thanking participants for their time and responses during this session.

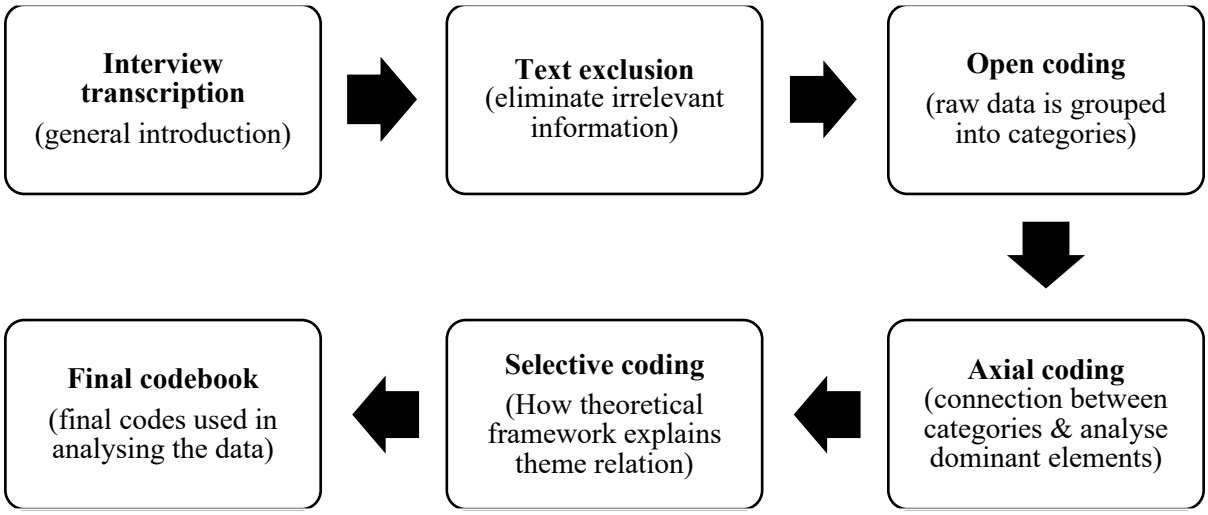
**3.4 Data analysis**

For the data analysis, thematic analysis from Braun et al. (2019) was used to analyze the focus groups and interviews. Qualitative data analysis software Amberscript assisted in transcribing the focus groups and interviews and ATLAS.ti was used for coding to identify key themes relevant to the research question. This process included becoming familiar with the data, generating initial codes, and grouping them into potential themes. These themes were then repeatedly reviewed, refined, and clearly defined to accurately represent the dataset.

The data analysis includes six stages, as illustrated in Figure 3. The focus groups and interviews were transcribed word-for-word, which results in 261 pages of transcripts. To protect confidentiality, all individuals referenced in the interviews were anonymized. The data analysis was based on Boeije's (2010) coding method, which consists of three clear phases. These phases were adapted to fit the context of this study and are explained in detail below.

**Figure 3.**

*Overview of the data analysis stages*




The open coding phase, which is the initial stage, involves a careful and comprehensive analysis of the data. Finding and classifying different ideas, topics, or categories that come up from the data is the main goal of this step (Boeije, 2010). This is why the interviews were first completely reviewed, and then every single phrase was evaluated. Important phrases were underlined and given a code that represented their main idea. The goal of this exploratory stage was to divide the data into more manageable, significant chunks without of any assumptions.

The next step, axial coding, builds on open coding by analyzing the links and interactions among the codes that have been identified (Boeije, 2010). Axial coding grouped initial codes into more general groups and subcategories by analyzing and organizing the links between the codes. To provide insight into the interactions and influences between various data fragments, patterns, connections, and hierarchies were found. To further understand their structure and relationships, these hierarchies were then represented as networks (attitude and knowledge,

perceived risks and advantages, communication preferences and source trust, and purchase intention of nano-packaged food).

To create an overall theoretical narrative, the established categories are refined and integrated in the final stage, known as selective coding (Boeije, 2010). The data was carefully coded to support or demonstrate the primary themes that best reflected the study question during this phase. Following a thorough comparison and evaluation of each code category to identify any new trends, the data was ultimately interpreted in an easy-to-understand way. The primary study topic was then definitively addressed by these interpretations.

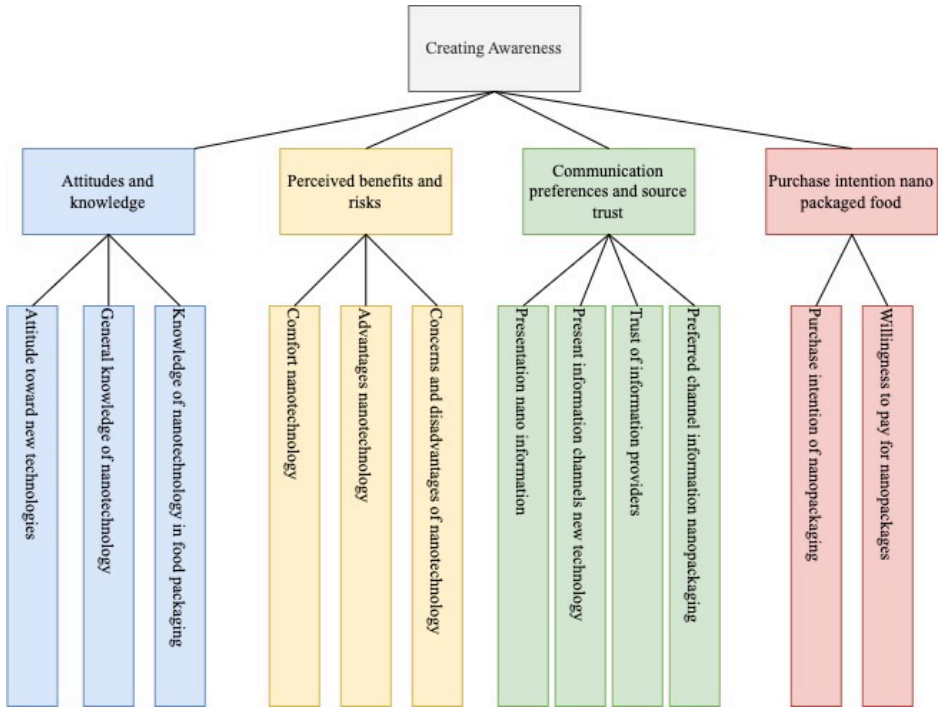
Furthermore, to improve the reliability of the coding process, a second coder independently reviewed a sample of 71 codes, which represented 10% of the total codes derived from the transcripts. Cohen's kappa was calculated and yielded a score of 0.761, indicating a reliable level of agreement (Landis & Koch, 1977). Small disagreements were discussed and solved by consensus, enhancing the thematic analysis's validity and coherence.

## 3. Results

This chapter presents a detailed thematic analytic analysis of the findings, providing insights into the research question. Four main themes have been identified that explain how to raise public awareness of nanotechnology in food packaging among the public. Each theme is supported by illustrative quotes from participants and is linked to corresponding main codes, sub-codes, and sub-sub-codes (see Figure 4). Based on the inductive analysis, the following main themes emerged: (1) attitudes and knowledge, (2) perceived benefits and risks, (3) communication preferences and source trust, and (4) purchase intention nano-packaged food. Appendix H: Code Networks provides an overview of the associated sub-codes and sub-sub-codes. The paragraphs below discuss these four themes to enhance the understanding of the study's results.

**Figure 4.**

*Set up of result section of this research*



### 4.1 Attitudes and knowledge

To answer how public awareness of nanotechnology in food packaging can be raised to reduce food waste, it is first essential to understand both public attitudes toward new technologies and the varying levels of knowledge about nanotechnology. See Appendix I, Table 3, for an overview of the attitudes and knowledge.

#### 4.1.1 Attitudes toward new technologies

Most participants in this study have a very positive attitude toward new technologies. Out of 22 participants, 20 rated their attitude between 8 and 10 on a scale of 1 to 10. This indicates in general a positive perspective. However, this enthusiasm was often accompanied by ambivalence and critical reflection. A total of 17 participants expressed positive feelings alongside reservations, particularly concerning the pace of technological progress and the need to maintain a human element in development. One participant illustrated this ambivalence clearly, combining enthusiasm with fear:

> *"Yes, new technologies, moving forward, discovering new things. Everything is becoming faster, better, and newer, which I think is generally very positive. However, why not a ten? Some technologies may not need to continue evolving. For instance, when I think about their applications in war, it becomes concerning. I realize that while some new technologies are beneficial, others can be quite frightening."* — Participant 6, focus group 1, not eco-conscious consumer.

This conflict between enthusiasm and concern was also noted by a nanotechnology expert. While consumer often expect innovation, they tend to resist often its actual implementation. As expert 1 explained:

> *“There's a kind of contradiction in that somewhere. We must develop and explore things, but then the transition to application or major use often encounters significant obstacles."* — Nanotechnology Expert 1.

This quotation emphasizes the seeming conflict between the public's desire for innovation and their resistance to its practical implementation, a recurrent subject among experts and consumers alike. The significance of incorporating the public in the creation of new technologies was also underlined by two more experts: a packaging technologist and a packaging technologist & inspector of the circular economy. They highlight that to increase acceptance rates; social influence must be considered while designing something new. Although they recognized that people generally have favorable feelings about new technologies, they also highlighted that people tend to follow their routines. This finding aligns with the quote from expert 3:

> *“Some people tend to get comfortable with what they are already familiar with. When something new comes along, it shouldn't be too difficult to adapt. So, I believe it’s important not to overthink it. The average consumer often exhibits this kind of behavior."* — Packaging Technologist Expert 3.

This response supports the insight that, while attitudes toward innovation are broadly positive, consumer habits and comfort with the status quo remain influential barriers to the acceptance and attitude of new technologies and technological change.

### 4.1.2 General knowledge of nanotechnology

This study also explored participants' general knowledge of nanotechnology. Across all focus groups, no participant demonstrated a clear or in-depth understanding of the concept. Most

responses were only vaguely familiar with the term or associated it with technologies such as microchips, medicine, or packaging coatings and often based on speculation or secondhand references. As Participant 2 in focus group 4 noted:

> *"I know very little about it; it's quite small. In healthcare, it does occur as well, such as detecting something via chips. But that's where my knowledge ends. So yeah, I don't know much about it."* — Participant 2, Focus group 4, eco-conscious consumer.

When asked about the source of their knowledge, most participants could not recall where or how they had learned about nanotechnology. Instead, they assumed they had encountered it informally through media, social conversations, or vague memories. Participant 4 illustrated this uncertainty:

> *"I have no idea anymore, but I thought I saw or heard it somewhere."* — Participant 4, Focus group 1, not eco-conscious consumer.

A small number of participants who worked in technical fields had come across the term in a more structured context, such as professional training or guided tours. Still, even among these individuals, detailed understanding remained limited. Moreover, these findings indicate that while nanotechnology is not entirely unknown to the public, its meaning and implications are poorly understood and often shaped by assumption rather than knowledge. This limited familiarity may pose challenges for informed decision-making and underlines the importance of targeted public communication of nanotechnology in general.

### 4.1.3 Knowledge of nanotechnology in food packaging

Participants were also asked about their knowledge of nanotechnology specifically in the context of food packaging. Of the 22 participants, 16 had little to no knowledge on the topic, while six displayed vague or speculative ideas. Participant 5 reflected this limited awareness by associating nanotechnology with antibacterial properties:

> *"Yes, I understand that you can influence various outcomes with that. For example, the antibacterial effect of, say, a product or something. Uh, so that bacteria are less likely to develop. So yeah, that kind of things."* — Participant 5, Focus group 3, not eco-conscious consumer.

Several other participants offered speculative guesses, such as: “Is it something that measures spoilage?”, “Maybe it involves extra plastic?”, or “Is it related to better shelf life?” While these responses sometimes hint at actual applications, they often reflect partial or incorrect assumptions. In addition, no differences were seen between eco-conscious consumers and not eco-conscious consumers. This indicates that, although nanotechnology is not entirely unfamiliar, its specific role in food packaging is poorly understood. This perception was confirmed by a nanotechnology expert, who noted that the public, and especially consumers outside the technical domain, often lack access to reliable, understandable definitions:

> *"Anyway, I understand why you might think people are unfamiliar with it, especially since there is no definition available anywhere on Google. In fact, there isn't one at all. This lack of information is even more pronounced in specialized fields like the food industry or whatever you are researching, which can make it feel completely unknown. In*

*contrast, topics like integrated circuits (ICs) and chips in electronics are much easier to find information about."* — Nanotechnology Expert 1.

The expert further emphasized that this knowledge gap is not surprising, and in fact, reveals much about current communication failures:

*"I'm not surprised that people think this way, it reflects how we communicate."* — Nanotechnology Expert 1.

These findings point to a need for clearer public communication and more targeted education about what nanotechnology in food packaging entails, to raise public awareness and understanding.

### 4.2 Perceived benefits and risks

Participants were first asked about their concerns and disadvantages related to nanotechnology, as well as its advantages. This inquiry aimed to address any concerns about the technology while also highlighting its benefits. Subsequently, participants were asked to indicate their comfort levels with nanotechnology to assess their food technology neophobia (FTN). See Appendix I, Table 4, for an overview of the perceived benefits, risks and the feeling of being comfortable with nanotechnology.

#### 4.2.1 Concerns and disadvantages of nanotechnology

Many participants expressed concerns about the technology itself, often citing a lack of clear and accessible information. This uncertainty led to questions about both health risks and long-term safety, as well as doubts about the sustainability of such packaging technologies. In addition, participants also held concerns about practicality and cost, and impact on consumer behavior. Participant 4, in focus group 4 mentioned that:

*"I'm not sure whether or not the materials used in the packaging have been studied, particularly with regard to the nanotechnology you use. What are the long-term risks associated with this? It raises some concerns for me. Additionally, how does this affect the sustainability of the packaging?"* — Participant 4, Focus group 4, not eco-conscious consumer.

Health-related fears were frequently mentioned, for example:

*"Is it harmful? Can it get into the food? If it is so small, can I breathe it in? If I touch it, does it get into my skin? Yes, and is that already bad?"* — Participant 1, Focus group 1, not eco-conscious consumer.

A second set of concerns centered on sustainability and environmental impact. In general participants questioned whether nanotechnology aligns with environmental goals. In addition, primarily eco-conscious consumers asks whether it might result in more packaging rather than less:

*"I think, should it all be packaged? It feels like an excuse to keep producing far away, because then it must be packaged."* — Participant 3, Focus group 4, eco-conscious consumer.

A nanotechnology expert confirmed that this uncertainty is common, especially when consumers are unfamiliar with the scientific mechanisms involved. But that it is helpful to then provide clear explanations:

*"When something is unknown, people begin to question its sustainability and safety. It's important to explain how it works and why it functions in that way, emphasizing that it is*

> *safe and beneficial. […]. And that it certainly works in your favor, especially if there are minimal or fewer disadvantages. I believe this is the strategy that every nanotechnologist should adopt when starting to work with commercial products."* — Nanotechnology Expert 1.

This view was also mentioned by the Packaging Technologist & Inspector of the Circular Economy, who emphasized the need for clearer communication, particularly regarding sustainability:

> *"I believe it's important to address the sustainability aspect, especially if it has no negative impact on it. It's important to explain how it contributes positively, such as by preventing food waste, for example."* — Packaging Technologist & Inspector of Waste Circular Economy Expert 2.

These findings demonstrate that public concerns about nanotechnology are multifaceted. They reveal uncertainties, health and safety issues, as well as practical and cost-related concerns. Further, there is little difference between eco-conscious and not eco-conscious consumers when it comes to the packaging of food products.

### 4.2.2 Advantages of nanotechnology in food packaging

In addition to concerns, many participants also recognized clear advantages associated with nanotechnology in food packaging. The most frequently mentioned benefit was the potential to reduce food waste which was reported by 14 of the 22 participants. As participants noted that extending shelf life would reduce unnecessary product disposal. Twelve participants also described how nanotechnology could improve efficiency and ease of use, particularly through color-based indicators that help staff or consumers quickly assess freshness. These

functionalities were seen as both user-friendly and timesaving. Additionally, the environmental impact was considered: less waste means fewer resources used. Participant 5 from focus group 2 summarized several of these perceived benefits in one detailed quote:

> *"Working with colors can be easier for the staff in the grocery store than reading through all that data. Overall, using color makes things more user-friendly, especially for people who wear glasses, as colors are easier to see than small text. Your example about being decomposable highlights its benefits for the environment. Additionally, using products that last longer helps reduce waste."* — Participant 5, Focus group 2, not eco-conscious consumer.

This quote demonstrates how multiple perceived benefits, usability, accessibility, sustainability, and environmental friendliness, were frequently interconnected in participants' reasoning. Moreover, while several participants expressed a desire to see these advantages communicated clearly, they were cautious about accepting such messaging when it appeared promotional or commercially motivated. As Participant 5 from another group noted:

> *"Also, it shouldn't come across as some kind of marketing tool. That consumers will think that they must throw it away again and buy something new so that companies will get more sales. While that may not be the case at all."* — Participant 5, Focus group 1, not eco-conscious consumer.

This tension was acknowledged by experts. Packaging Expert 3 emphasized the importance of clarity and tailoring communication to different audiences:

*"I believe that the way we communicate with consumers is very different from how we communicate with manufacturers or professionals like ourselves. When it comes to packaging, it's important to clearly explain what is happening without diving too deep into technical details. People tend to prefer simple explanations, like using a traffic light as a metaphor."* — Packaging Technologist Expert 3.

*"In the end, it may be more effective for professionals to focus on explaining specific technologies rather than discussing nanotechnology, as the term itself is quite broad. There is often more communication surrounding applications of nanotechnology, such as its use in certain types of food packaging. Therefore, the key to successful communication lies in understanding the target audience and tailoring the message accordingly."* — Packaging Technologist Expert 3.

These results highlight that although consumers are aware of the useful and environmentally friendly benefits of nanotechnology, communication style and trust are still important adoption determinants. Benefits should be communicated in a straightforward and practical manner, eliminating connotations of deception or sales techniques.

### 4.2.3 Feeling comfortable with nanotechnology in food packaging

After discussing the advantages and disadvantages of nanotechnology in food packaging, participants were asked to rate their personal level of comfort with the technology on a scale from 1 to 10. The results revealed a wide range of comfort levels, with the majority falling within the moderate to high range. Specifically, 16 participants gave ratings between 4 and 7, indicating a moderate level of comfort, while 13 participants gave ratings between 8 and 10, suggesting high comfort. These figures exceed the total number of participants (N=22), as some

individuals adjusted their rating during the discussion or expressed a range of scores. Only two participants rated their comfort level below 4.

One significant difference between eco-conscious and not eco-conscious consumers their comfort level with nanotechnology in food packaging. Eco-conscious consumers generally expressed greater comfort with this technology. In contrast not eco-conscious consumers reported a moderate to high comfort level, but they also had doubts. A common reason for hesitation among those reporting lower comfort was a lack of knowledge or uncertainty about how the technology functions. Several participants expressed a desire for more trustworthy information, regulatory clarity, and consumer-oriented explanation. As one participant noted:

> *"Yes, how is that going? Can it contaminate the food? How is it heated? I'm curious about the process. Normally, I would have chosen the orange package, but I decided against it this time. It's important to have information, education, and reliability in these matters."* — Participant 4, Focus group 1, not eco-conscious consumer.

In contrast, other participants, regardless of whether they were classified as sustainability-oriented or not, displayed a high degree of trust in the system. They expressed that if a product is available in supermarkets, they assume it has passed all necessary safety checks. This contradicts precisely what others are saying, that they want even more confidence in the regulation and legislation. Participant 7 stated:

> *"I have the feeling that when people don't think about it too much, they might just see something in the store and decide to buy it without considering the rules and regulations. Many consumers might not even realize the implications involved."* — Participant 7, Focus group 2, not eco-conscious consumer.

Similarly, a participant from the eco-conscious consumer group added:

> *"Yes, many people don't look too deeply into things, so the saying 'what you don't know won't hurt you' holds some truth. In general, I believe consumers will simply buy products without giving much thought to whether the packaging is safe. In fact, I think that if you start informing people about the ingredients or materials, they may become uncomfortable, as they might worry there are harmful substances in the product."* — Participant 6, Focus group 4, eco-conscious consumer.

The results show that perceived safety often rely on the general public's trust in institutions and regulatory frameworks rather than only technological expertise. Some participants indicated that they wanted in-depth information, while others would rather stay away from technical details. This suggest that different levels of desired involvement and comfort should be considered in communication tactics. In addition, experts advise that it is important to discuss this technology in a clear, simple, and approachable way to reduce consumer concerns and improve transparency. This was highlighted by an expert in nanotechnology:

> *"It's best to explain this in simple terms, using clear and straightforward language, like that in "Jip and Janneke." We should focus on answering key questions: What are the benefits? How is it safe? What does it do? It's essential to be honest about these points. If there's something that might seem unclear or negative, recognize it. […] We should be transparent and not leave out any important details, as those will naturally come to light."* — Nanotechnology Expert 1.

In line with this, packaging experts suggested not overloading packaging with technical information, but instead using tools like QR codes to allow curious consumers to access further details if desired:

> *"I don't think this is something you should be putting on the packaging itself anyway, because no one is going to read that. And the more you start explaining on a package, the more you also give a bit of the idea of "we have to defend ourselves." I would keep it short and simple, perhaps including a QR code. This could serve as a prompt for people to indicate if they want more information about the technology or how it works. By scanning the code, they could be directed to a website that provides more detailed explanations."* — Packaging Technologist & Inspector of Waste Circular Economy Expert 2.

Another expert added that while consumers often claim to want more information, they rarely act on it:

> *"I agree that providing too much information overwhelm people, making it difficult for them to understand. They might wonder, 'What is all this about?' While there will always be critical consumers who express a desire for more information, many individuals not actually take the time to read it or may not be waiting for it at all."* — Packaging Technologist Expert 3.

Furthermore, another insight shared by the Packaging Technologist is that consumers often express a lack of confidence regarding packaging. However, when the packaging is perceived as commercially useful, this confidence increases. For instance, with "tamper-evident"

packaging, consumers can easily see if a package has been opened. The expert notes from experience that very few, if any, consumers in a supermarket check each package to see if it has been tampered with. Instead, they tend to trust that the package is sealed. This indicates that while consumers may initially feel concerned and lack confidence during focus group discussions, they ultimately tend to relax their concerns.

The same expert mentioned that focus group participants find the term "nanotechnology" intimidating because they are unfamiliar with it. However, many packaging materials already incorporate coatings and barriers that use kind of nanotechnologies, even if they don't explicitly fall under that label, perhaps because they are too thick to be classified as such. The same expert believe that many people are unaware that these products are already in use. Additionally, it seems that using complex terminology may decrease people's comfort and acceptance of these technologies.

### 4.3 Communication preferences and source trust

In this section, participants were asked about their communication preferences and trust in information sources. They discussed how they engage with new technologies, which information providers they trust, and their preferred channels for receiving information about nano packaging. In addition, they shared their preferences for how this information should be presented and where they would like to access it. See Appendix I, Table 5, for an overview of the communication preferences and source trust.

#### 4.3.1 Present information channels new technologies

The results indicate that participants frequently cite social media as a source of information about emerging technologies. However no single platform became the dominant

one. Seven people mentioned LinkedIn, although mostly in reference to following professional associations or institutions. Instagram (five participants) and TikTok (four participants) were also noted as platforms where technology-related content occasionally surfaced. Other sources identified were Rabbit, Facebook, and YouTube. Notably, several interviewees clarified that they usually utilize streaming services like Netflix or Discovery+ to look for specific information through documentaries or television shows rather than passively. Many participants struggled to recall where they learned about new technologies, indicating a lack of awareness regarding their consumption of information about such technologies.

In addition to online platforms, traditional media was also mentioned. Television, especially talk shows like Beau and Jinek, and national broadcasters such as NOS, emerged as common sources. Magazines such as Kijk or Quest, and particularly local newspapers, were cited more often by participants over the age of 30. In contrast, younger participants under 30 relied more on online and algorithm-driven content. Participants also referred to personal networks as important information channels. They described gaining insights about technologies through workplace settings, friends, or acquaintances with expertise in scientific or technical domains. The following quotes illustrate these findings:

> *“Well, then something comes along on one of the social media channels about what they're working on or what it can do.”* — Participant 4, Focus group 2, not eco-conscious consumer.

> *"Especially social media and the news. The apps for news are important, but also your personal environment and network. Yes, regular information sources and news, such as television programs. News broadcasts and talk shows can be useful as well, especially if*

*there happens to be an interesting guest."* — Participant 5, Focus group 3, not eco-conscious consumer.

As mentioned earlier, it appears that consumers are often unaware of how they gather information about new technologies. No single platform truly dominates this process, and consumers struggle to identify specific sources of information. After discussing these findings with a nanotechnology expert, he posed a question that underscored this observation:

*"Are people actually aware of how they consume that kind of information? So, it's more the reverse questions to answers."* — Nanotechnology Expert 1.

Moreover, a participant mentioned that they often only become aware of technologies once they are already in use:

*"I often find that I don't notice something until it has already happened. The first stages leading up to it usually pass me by without much awareness. But, once something is implemented, I definitely notice it."* — Participant 6, Focus group 4, eco-conscious consumer.

These insights suggest that while many participants are exposed to information across multiple media, their engagement is often passive, fragmented, or delayed. Most people do not actively seek out information about emerging technologies until implementation is visible or relevant to them.

### 4.3.2 Trust in information providers

The focus group discussions show important insights into how trust in information providers influences the perceived credibility of information about nanotechnology. The analysis

of 28 relevant quotations indicates that the platform, source, and presentation style of the message play a key role in participants' judgments of trustworthiness. Participants expressed clear skepticism toward sources that are perceived as being commercially motivated. If information appears to present a marketing purpose, such as influencer endorsements or product placements, it is more likely to be dismissed. A quotation which fits these results:

> *"I believe there is a significant difference between recommendations that come from a commercial angle, such as influencers endorsing products for sponsorship, and those given by someone genuinely sharing their expertise. When a scientist speaks about their area of expertise, research, or interest without any personal benefit, I feel much more confident in their statements. In contrast, when someone is promoting a product for financial gain, it raises my skepticism, and I tend to think, 'You're only saying this for the money.'"* — Participant 5, Focus group 3, not eco-conscious consumer.

Perceived reliability is also influenced by the medium used to communicate information. Because of a huge amount of false information and the absence of regulations, social media platforms like Facebook, Instagram, and TikTok were frequently seen as less reliable. "Anyone can post anything" on these platforms, according to the participants. Additionally, many people thought that channels with a small number of followers or a low view count were less reliable.

Conversely, strong trust was expressed in scientific institutions and independent authorities, supported by 31 citations. Participants identified scientists, professors, and experts as trustworthy because they are perceived to be objective, research-based, and ethically reviewed. Governmental organizations and public broadcasters such as NOS were also seen as reliable sources of information, with 20 citations.

Although fewer in number, some participants also trusted public figures or well-known experts, provided they demonstrated topic-specific expertise. In general, repeated exposure, factual content, and a neutral tone were all seen as crucial in creating trust. Following these findings, experts offered reflections on the importance of proactive science communication. A nanotechnology expert emphasized that although universities and research institutions are trusted, they often do not publish in accessible ways:

> *"Universities should communicate their work in clear and understandable language."* — Nanotechnology Expert 1.

This perspective was also mentioned by the Packaging Technologist expert, who highlighted the value of using social media to increase public exposure to scientific knowledge:

> *"I believe it's important for institutions to be present on platforms like Instagram to share their activities and updates. However, I realize that this approach may not always be effective, especially for those technologies. For instance, when people often hear about topics like AI, they might think, 'I want to learn more about that.' In those cases, they may seek information from a university or similar institution to trust the credibility of what they hear."* — Packaging Technologist Expert 3.

These findings show that trust is shaped not only by who communicates (e.g., scientists vs. influencers), but also by how and where communication occurs. Scientific institutions and independent bodies are seen as credible but must ensure that their messages are accessible and visible in the spaces where consumers already engage.

### 4.3.3 Preferred channels information nano packaging

Twelve respondents say they favor traditional media sources when it comes to learning about nano packaging in food. This covers ads on radio, TV, NOS, and newspapers. The senior population, in especially those 30 years of age and older, is where this trend is most noticeable. Additionally, this group highlights how important it is to consider older generations, who might not have access to social media. For them, the best locations to gain knowledge would be public spaces like libraries or local shops like greengrocers.

In contrast, seven participants preferred digital platforms, particularly social media. While some again mentioned NOS, they referred more to the online channels associated with this medium. Additionally, they primarily pointed out the social media platforms discussed in section 4.2.2 regarding trust in information providers. Ideally, participants in this study expressed a desire to obtain information directly in supermarkets, particularly at the products that are packaged with nanomaterials.

A quotation that was mentioned often is like this:

> *"I believe that when products are displayed in the supermarket, there needs to be some kind of informational signage. Additionally, at a certain point, the meaning behind that messaging should be communicated more broadly through traditional media. We saw a similar situation with the Nutri-Score; initially, very few people understood what it was. Therefore, it's important to make that message clear from the start."* — Participant 6, Focus group 4, eco-conscious consumer.

Participants indicated a clear preference for receiving information about nanotechnology in food packaging through trusted and familiar channels. While older participants favored

traditional media, younger individuals leaned toward digital platforms. Across all groups, a preferred location for communication was the supermarket itself, underscoring the importance of clear, visible information at the point of purchase. However, before consuming this information in a supermarket, they expect widespread communication beforehand.

### 4.3.4 Presentation nano information

This part explores how information about nanotechnology in food packaging should be presented to the public. Based on 44 participant comments, the preferred communication style is short, clear, and accessible. Many participants mentioned that they would not engage with long-form content such as full A4 pages or videos longer than one minute. Instead, they preferred concise explanations that focus on the practical advantages of the technology, ideally in everyday language. Most respondents (25 citations) expressed a preference for visual or audiovisual formats. Short videos, simple graphics, and even radio messages were mentioned as engaging tools. Visual communication was appreciated for its accessibility, with participants noting that long texts or highly technical explanations reduce attention and motivation. One participant explained:

> *"I believe that the pictures you presented at the beginning, which may come across as somewhat childlike, have a universal appeal for people of all ages. We are naturally visual beings, and when faced with long texts, we often lose interest quickly. This tendency is especially true when the content includes technical information."* — Participant 3, Focus group 2, not eco-conscious consumer.

While concise in-store information was seen as essential, many also supported the use of *QR codes* to allow for deeper exploration at home:

> *"In the supermarket, you are often in more of a hurry. I would prefer to scan a QR code and check it at home."* — Participant 5, Focus group 3, not eco-conscious consumer.

The physical location and accessibility of information also played a role. With 36 citations, participants emphasized that information should be visibly available in supermarkets, ideally next to the product or on the packaging. Supermarket magazines and apps were also mentioned as effective complementary tools:

> *"Yes, or place brochures or other materials next to the shelves. This way, if someone wants more information, they can take a brochure or folder and read it at home."* — Participant 5, Focus group 1, not eco-conscious consumer.

In terms of *tone and trust*, participants preferred neutral, factual communication that avoids commercial language. They indicated that trust is best built through sources perceived as credible, such as researchers or scientists, especially when communication is based on actual research and not sales-driven narratives. These preferences were confirmed by experts. A nanotechnology specialist emphasized that older and younger audiences have distinct information needs, with older people still preferring written formats or more traditional ways, while younger consumers lean toward digital tools:

> *"Older people tend to read newspapers, whether digital or print. In contrast, young people view them differently. Yes, I do understand that, and so I also understand this answer."* — Nanotechnology Expert 1.

Although the Packaging Technologist was critical of public broadcasters such as NOS for not having a suitable format for technical innovations, they did see value in using QR codes:

*"I think it can be a bit challenging for NOS, because NOS tend to focus on news that has some level of urgency or impact, which often means they cover negative stories. For example, there was a recent breakthrough in breast cancer research that received attention. While NOS may not present as a knowledge base for scientific advancements, other public broadcasters have the capacity to produce in-depth episodes on such topics. They could include interviews with researchers or provide detailed analyses to better inform the public."* — Packaging Technologist Expert 3.

While public broadcasters such as NOS were considered less suitable for communicating complex technologies, Packaging Technologist Expert 3 saw opportunities in using other formats, such as QR-codes or interviews in consumer-oriented media. This expert also highlighted the role of collaborative communication between universities, producers, and retailers:

*"I think what Expert 2 mentioned about QR codes is important. They are useful for consumers who want more information. More recent, I heard that the European Union is planning to add more QR codes on packaging. This would allow for additional information to be provided without overcrowding the packaging itself. […]. Overall, I think offering QR codes could be a good option for consumers."* — Packaging Technologist Expert 3.

*"First, researchers need to clarify how the new technology should be implemented. Following that, manufacturers will adopt this technology and communicate its benefits to consumers. As a result, consumers may start to think, 'This is something new that I don't understand, and I want to learn more about it from a trusted source.' This can lead to*

*communication between, for example, universities and consumers, creating a kind of circle or triangle of interaction."* — Packaging Technologist Expert 3.

Participants preferred brief, visually engaging, and easily accessible communication about nanotechnology in food packaging. QR-codes, in-store materials, and neutral messaging from trusted sources were seen as most effective. Communication strategies should be adapted to different age groups and combine product-level information with broader outreach through trusted intermediaries such as scientists or public institutions.

### 4.4 Purchase intention nano-packaged food

This chapter presents the results of the focus group study exploring participants' intentions to purchase food packaged with nanotechnology. It in particular asks participants if they are comfortable and confident in their choice to purchase such goods. The chapter also investigates whether they would be willing to pay more for food that is packed with nanotechnology. First, the discussion will examine the participants' intentions regarding nano packaging. See Appendix I, Table 6, for an overview of the purchase intention of nano-packaged food.

#### 4.4.1 Purchase intention of nano packaging

To assess consumer willingness to purchase nano-packaged food, participants were asked to indicate their intent on a scale from 1 to 10. With 21 quotes indicating moderate to high purchase intentions, the overall sentiment toward nanotechnology in food packaging was mostly positive. A frequently expressed view reflects both interest and openness, especially if the packaging is transparently available in supermarkets and perceived as safe:

> *“If the supermarket is full of it, then definitely a ten and now? Uh yeah, I'm always curious too, so I think I'm going to investigate that. Or just check and if it's safe enough, then I dare to do that now too. Yes, of course.”* — Participant 5, Focus group 3, not eco-conscious consumer.

The eco-conscious consumers all expressed a strong willingness to purchase food packaged with nanotechnology. However, when given the option, they preferred food that does not come with any packaging:

> *“I would definitely buy it. No problem. Well, if it’s unpackaged and I’m going to use it right away, I will prefer unpackaged.”* — Participant 5, Focus group 4, eco-conscious consumer.

Despite the inclusion of 12 quotes, many questions remain about the intentions behind them. Most doubts come from not eco-conscious consumers, whose primary concern is the need for additional information to create trust. This concern is underscored by 14 quotes that highlight their desire for transparency:

> *"I'm currently undecided, so I say a five for now. I think it's a good idea, but I feel there isn't enough information available yet. If it proves to work well and the risks are minimal, I will consider purchasing it. However, for now, I remain uncertain because more information is needed."* — Participant 5, Focus group 1, not eco-conscious consumer.

A nanotechnology expert supported this observation by stating:

> *"Yes, but that goes together, right? If you have more information and your confidence increases as a result, the likelihood of a purchase also increases and then it becomes easier, right?"* — Nanotechnology Expert 1.

The possible price increase and whether this technology would be used for all food products, not just fresh ones, were the other two significant areas of uncertainty. Before considering greater intention to purchase, several participants wished to understand more about the rules and regulations around this technology since they were unsure. Six quotes, representing a minority of participants, indicated low buying intentions. Their daily grocery shopping and their unwillingness to perceive the benefit of a longer shelf life were the reasons behind this rejection. The Packaging Technologist Expert said they understood the different opinions and purchase intentions:

> *"I can imagine that reactions to this topic are very diverse because there are many different examples. As you pointed out, nanotechnology depends on the specific application and how consumers perceive it. For instance, in the first example where a sensor is not visible, but the packaging has a shelf life that is twice as long, it's understandable that consumers might wonder about this. However, if the benefits of this technology are clearly communicated, I believe consumers will be more accepting. You don't necessarily need to label it as nanotechnology, simply referring to it as a type of packaging with an extended shelf life would suffice. If it involves a sticker, for example, it might be helpful to provide additional information through a QR code. In the end, the response will vary depending on the specific application, so I can certainly understand the range of reactions this might provoke."* — Packaging Technologist Expert 3.

The expert added that buying intention is influenced by product exposure and usefulness. Customers might be more open to paying a higher price, for instance, if they can see a freshness sensor or enjoy a longer shelf life. On the other hand, unexplained technological aspects could cause distrust. Emphasizing the benefits to the customer is crucial for conversion, according to Packaging Technologist & Inspector of Waste Circular Economy Expert 2:

> *"Yes, I believe you should emphasize the added value for consumers. Some people say, 'I wouldn't pay extra for it because I go to the supermarket every day and buy fresh products.' I don't think it's worth trying to persuade them further. However, if you communicate that your milk will now last longer at home, people might consider choosing this package over others on the shelf."* — Packaging Technologist & Inspector of Waste Circular Economy Expert 2.

While purchase intentions for nano-packaged food are generally high, they are often *conditional* on clear, trustworthy, and product-specific information. Eco-conscious consumers remain willing but cautious, and price sensitivity plays a role.

### 4.4.2 Willingness to pay for nano packaging

This final subsection explores participants' willingness to pay a higher price for food products packaged using nanotechnology. Only two participants explicitly stated that they would unconditionally be willing to pay more for such products, which were eco-conscious consumers. The vast majority, 19 out of 22, expressed conditional willingness. This group highlight that their decision depends on knowing the added cost in advance and understanding how the technology would offer direct personal benefit, such as reducing food waste. For instance, many participants stated that they would only be willing to pay more if it became clear that the

technology helped avoid throwing away food that was still safe to eat. This reasoning was illustrated by the following quote:

> *"I believe it would be important if they could show that I tend to throw away a big amount of meat or fish. If they can show that reducing waste could ultimately save me money, I would be more willing to pay extra. However, I'd need to understand the cost difference first. It's important to weigh these factors against one another."* — Participant 1, Focus group 3, not eco-conscious consumer.

Participants also made a distinction between fresh food and non-perishable items. Several noted they would not pay more for products like pasta or rice, but would consider it for fresh produce, meat, or dairy. One participant explicitly declined to pay more, citing personal financial limitations. The eco-conscious consumer group took a broader view. While they, too, emphasized proportionality, their willingness to pay was often rooted in global or ethical motivations:

> *"Yes, I would be willing to pay more for it. If you look at the global scale and we can do something about that, about the great food shortage in the world through nanotechnology. Then I would be willing to pay a little more. And of course, that also depends on the proportions."* — Participant 2, Focus group 4, eco-conscious consumer.

These findings reflect a recurring pattern: price sensitivity remains a key barrier, even among consumers who support the technology in principle. This tension was acknowledged by a nanotechnology expert, who observed:

> *"Unfortunately, this is often the reality in the consumer society we live in today. Many times, the focus is primarily on ease of use or profit. Environmental benefits are*

*mentioned, but they usually come second, third, or even fourth in importance. This is quite strange."* — Nanotechnology Expert 1.

The same expert suggested that structural support or government intervention may be required to normalize such technologies and overcome consumer hesitancy:

*"The government must impose this to ensure reasonable outcomes. People are diverse, and this is typically Dutch, leading to varied choices."* — Nanotechnology Expert 1.

Finally, the Packaging Technologist emphasized that price, brand, and quality typically dominate often consumer decision-making. Aspects like durability or longer shelf life often remain secondary in purchasing behavior. This insight helps to explain why many participants, though interested, require clear added value before accepting a higher price.

In general, the results show that consumers still have little awareness of nanotechnology in food packaging and many participants have limited knowledge of the technology. As a result, most people expressed positive opinions about nanotechnology, and more open communication could make people more willing to use it. The results also showed that neophobia of food technology is often caused by a lack of knowledge rather than fear of the science, indicating that resistance can be reduced through more transparency and trust. Effective communication involves the use of known and trusted sources, such as public broadcasters and universities. Participants preferred information that was clear, easy to understand and accessible, especially when it came from trusted sources such as supermarkets and QR codes on packaging. Experts indicate that it is more important to frame the benefits of the technology, such as reducing food waste, more broadly than the term "nanotechnology." These insights and their implications are discussed further in the main findings.

# 4. Discussion

## 5.1 Main findings

This study explored how to raise public awareness of nanotechnology in food packaging through four focus groups and two expert interviews with three experts. Consistent with previous studies (e.g., Cobb & Macoubrie, 2004; Hart et al., 2007; Kahan et al., 2007; Pérez-Esteve et al., 2022), participants showed limited knowledge, often associating nanotechnology with chips or medicine. Experts confirmed this knowledge gap and emphasized the importance of clear, accessible communication via trusted institutions.

Concerns centered around health, safety, and sustainability, mainly due to a lack of reliable information, which is a repetition of earlier findings by Greehy et al. (2011), Aday and Yener (2015), Spence et al. (2018), and O'Callaghan and Kerry (2016). Eco-conscious consumers were more open to nanotechnology, motivated by ethical and environmental concerns, but questioned whether it would lead to more packaging. Not eco-conscious consumers were more hesitant, seeking clarity on risks and benefits. Despite these concerns, many participants acknowledged advantages such as reduced food waste, improved usability, and environmental benefits. These findings underline that while consumers recognize the potential of nanotechnology, communication style and trust remain critical for adoption.

Moreover, measured FTN levels were moderate to high, slightly above global averages measured by Pérez-Esteve et al. (2022), Gómez-Llorente et al. (2022), Garrido et al. (2021), Kuang et al. (2020), Coutinho et al. (2021), Evans et al. (2010), Matin et al. (2012), and Verneau et al. (2014), where FTN scores were generally neutral. Eco-conscious consumers expressed greater comfort with the technology, while not eco-conscious consumer often expressed doubts,

mostly due to limited knowledge or uncertainty about its functioning. Several participants called for more trustworthy information, regulatory clarity, and consumer-oriented explanation. In contrast, others, regardless of their sustainability orientation, showed high trust in regulations and legislations, assuming that supermarket availability indicates safety approval. This confidence stands in contrast to those requesting more assurance in regulation and legislation.

Participants frequently cited social media as a source of information, yet few could recall specifics, indicating a low awareness of how they consume technology related content. Older participants leaned on traditional media, while younger ones engaged more passively through algorithm-driven platforms. This passive exposure raises doubts, also mentioned by Siddiqui et al. (2022), about whether consumers are aware of new technologies before encountering them in practice, with the suggestion that consumers are often seen as “less informed”.

Trust was closely tied to perceived independence: scientists and public institutions were seen as reliable, whereas influencers and commercial sources evoked skepticism. Participants favored familiar, practical communication, such as QR codes, labels, or supermarket signage. Experts warned against defensive packaging texts and advocated layered messaging tailored to different audiences via QR codes on packages which is also recommended by EU for future packaging (Stemerding, 2025). Experts proposed also a three-step strategy: scientists introduce the technology, manufacturers communicate its use, and consumers access information in-store and online, supported by trusted institutions.

Moreover, an expert raised a question about whether we should communicate information regarding nanotechnology. The term itself is very broad and vague, and consumers generally lack knowledge about it. When these products are commercially available, they must

be safe. Therefore, an expert suggested that instead of using the term "nanotechnology," we should focus on communicating that there is a new packaging solution that helps extend product shelf life and offers various benefits.

Finally, most participants were willing to buy food packaged with nanotechnology, especially when available in supermarkets and perceived as safe. Eco-conscious consumers were more accepting, driven by global and ethical concerns, though they preferred unpackaged food. Not eco-conscious consumers were more hesitant and demanded reliable, clear information. Willingness to pay extra was conditional and primarily linked to fresh products prone to spoilage, echoing earlier concerns from Greehy et al. (2011), Aday and Yener (2015), and Spence et al. (2018) that higher prices may lower purchase intentions. Experts mention that clear value communication and trust in regulation are important and called for public campaigns or legislation to support acceptance.

In summary, this study demonstrates that raising public awareness of nanotechnology in food packaging requires more than simply providing information. It involves targeted, transparent and audience-specific communication. Awareness can be increased by using trusted sources such as universities and public broadcasters, familiar formats like packaging labels and QR codes, and framing messages around functional benefits such as extended shelf life rather than complex scientific terms. Furthermore, a phased strategy—where scientists introduce the technology, manufacturers communicate transparently, and consumers access information via trusted platforms—can help translate abstract concepts into tangible understanding.

### 5.2 Theoretical implications

Previous studies have often highlighted risk perception, perceived benefits, and knowledge levels as the main factors influencing technology acceptance (e.g., Capon et al., 2015; Erdem, 2018; Gómez-Llorente et al., 2022; Pérez-Esteve et al., 2022). In contrast, this study focuses on how to create awareness of these factors.

The findings show that consumers generally have limited prior knowledge of nanotechnology in food packaging, and that this lack of familiarity contributes to uncertainty and hesitation. This study also shows that, over the years, the knowledge levels of nanotechnology in food packaging have not improved. Research by Cobb and Macoubrie (2004), Hart et al. (2007) and Kahan et al. (2007) already showed that over two-thirds of their respondents had heard “a little” or “nothing” about the technology. More recently, Pérez-Esteve et al. (2022) found similar results. Rather than outright rejection, this study shows that consumers adopt a “wait-and-see” attitude, indicating that acceptance is conditional and dependent on access to clear, reliable, and contextually relevant information.

Additionally, this study extends existing models such as the Food Technology Neophobia Scale (FTNS) (Chen, 2018; Chen et al., 2013; Nucci & Hallman, 2015; Cattaneo et al., 2018; Egolf et al., 2019) by showing that aversion to nano packaging or food technologies does not necessarily arise from fear or distrust of science, but rather from an information gap. This suggests that neophobia may, in some cases, be a temporary condition rather than a stable consumer trait. In turn, this research contributes to discussions on cognitive openness and attitude formation regarding technological unfamiliarity. It further underscores the role of communication in reducing neophobia by addressing informational gaps and increasing

perceived transparency. Effective and accessible communication strategies may therefore facilitate attitude change and create greater openness toward unfamiliar food technologies. Information presentation, or framing, has a big impact on how people interpret it. Entman (1993) argues that framing is the process of highlighting specific aspects of reality to influence how individuals perceive issues. Effective framing can fill in knowledge gaps by emphasizing the advantages of nano packaging, especially those pertaining to sustainability, safety, and health. Positive attitudes and greater acceptance of nano packaging can be created by communication strategies that prioritize transparency and match technology with consumer values. By lowering the neophobic responses that are frequently linked to new food technologies, this strategy can increase consumer trust and openness.

Moreover, this study contributes to knowledge about consumers' decision-making on sustainable innovation. Although previous research shows that consumers express support for environmentally friendly packaging, their willingness to pay is often limited (Hao et al., 2019). This study nuances those findings by showing that perceived personal utility, such as packaging that extends shelf life or provides freshness indicators, can significantly increase willingness to pay. This suggests that consumer preferences are driven not only by environmental concerns or abstract sustainability goals, but also by practical and tangible benefits in everyday life. This insight offers a theoretical refinement of value-behavior models and suggests that functional benefits may serve as mediators between sustainability values and purchase intention.

Furthermore, this research contributes to theoretical frameworks on how consumers acquire and evaluate information in relation to emerging technologies. While classic models such as the Elaboration Likelihood Model (Petty & Cacioppo, 1986) describe central and peripheral routes, the findings in this study suggest a more nuanced form of engagement. Many

participants reported a preference for accessible entrances to technology without being overwhelmed by technical jargon or marketing techniques. This preference for modular and self-directed learning could provide new models for designing technological communication, especially in supermarkets and retail stores where decisions are made quickly and often intuitively.

Finally, this study contributes to the literature on science communication by examining how consumers prefer to receive information about new food technologies. While previous research emphasizes the importance of scientific knowledge and transparency (Bubela et al., 2009), the findings here show that message formatting, tone, and timing are just as important. Participants indicated a preference for short, understandable, and accessible messages at the point of sale, supported by deeper layers of information via QR codes. This layered approach suggests a possible new communication model in which building trust and consumer engagement are prioritized over technical details. Such an approach aligns with discussions in the science communication literature on audience engagement (Nisbet & Scheufele, 2009; Dahlstrom & Scheufele, 2018).

### 5.3 Practical implications

The study's findings provide valuable information about how we can raise public awareness of nanotechnology in food packaging to reduce food waste. These findings have several practical implications for policymakers, science communicators, manufacturers, and other stakeholders who aim to implement such innovations effective and responsive.

Since the application of nanotechnology in food packaging is still in its early stages, communication strategies must be developed proactively before large-scale market introduction.

A key finding is the considerable knowledge gap among consumers. Most participants were unfamiliar with the term nanotechnology or misunderstood its meaning and applications. This underlines the urgent need for targeted awareness campaigns that not only explain what nanotechnology is, but also highlight its tangible benefits, such as extended shelf life and waste reduction. Timely and transparent communication can prevent misinformation, reduce consumer resistance, and create acceptance.

In addition, communication must be tailored to different target groups and media. Results show that older consumers prefer traditional channels, while younger consumers rely more on digital platforms and streaming services. In-store communication, especially at the point of purchase, emerged as a critical moment for decision-making. Tools such as visual labels and QR codes linking to accessible explanations were seen as highly effective. Therefore, stakeholders should adopt multi-layered strategies: brief and accessible messaging supported by optional, in-depth information online.

Thirdly, to support the broader goal of reducing food waste, as set out in the UN's aim to halve global food waste by 2030 (Rijksoverheid, 2010), behavioral change is needed. Consumers should be encouraged to choose food that is close to expiration if they intend to consume it directly. They must be reassured that such products remain safe due to the application of nanotechnology. This helps make products with longer shelf lives available for those needing longer storage, thus reducing waste. Promoting such conscious shopping behavior could be part of supermarket and sustainability campaigns.

Public trust is highest in independent scientific institutions, universities, and public broadcasters, while influencers and commercial messaging are met with skepticism. Science

communicators and public institutions should therefore take a more proactive role in communicating about nanotechnology. This should not only involve peer-reviewed publications but also include social media, collaboration with supermarkets, and citizen outreach programs. These communications must be transparent, jargon-free, and honest about limitations, helping to build long-term public confidence.

Eco-conscious consumers, though supportive of innovations that address global issues like food safety, also mention the importance of reducing packaging overall. This introduces a clear challenge: nano packaging may reduce spoilage but must also align with circular economy principles. Manufacturers and policymakers should communicate how such packaging solutions support environmental goals and why packaged food is not necessarily harmful for the planet.

This study also suggests a multi-step framework. Universities and research institutions can act as initiators of accessible communication for consumers. Packaging manufacturers and food producers should implement nano solutions transparently and indicate usage through clear labeling and QR codes, as supported by EU visions. Additionally, governments can further support public awareness through policy incentives and regulation, in company with public education in collaboration with scientific institutions and broadcasters. And finally, consumers access information via trusted platforms.

By acting now and aligning technological innovation with public understanding and regulatory support, stakeholders can play a significant role in creating a more sustainable and well-informed food system.

### 5.4 Limitations and future research

First, although one expert interview was conducted with a nanotechnology specialist, this individual lacked specific expertise in food packaging. This limited the depth of technical insights. Future studies would benefit from interviewing experts with a more focused background in nanotechnology applications within food packaging. Such input could enrich the interpretation of consumer concerns and support more targeted communication strategies for industry and academia.

Second, participants in the focus groups often asked technical questions about nanotechnology that the moderator was unable to completely answer. The researcher concluded from this, that participants wanted more initial information. It's crucial to remember, as well, that a lot of participants also indicated a wish to see long-term research findings. An assistant moderator with domain-specific expertise in nanotechnology could be beneficial for further research. To promptly and accurately answering technical questions, this assistant ideally should have knowledge of nanotechnology. According to Morrison-Beedy et al. (2001), assistant moderators play a crucial role in managing group dynamics, non-verbal cues, and ensuring responses are sufficiently detailed. Their presence would also help field technical questions accurately and maintain the flow of discussion.

Additionally, by creating tangible packaging and communication prototypes based on the existing findings, future research could adopt a more relevant approach. A/B testing or focus groups could be utilized to determine public preferences and the efficacy of the message (Quin et al., 2024). This would facilitate getting consumer insights into practice and help apply nanotechnology in food packaging in a way that is both successful and socially acceptable. A

key research question for future studies should be: *"How do different communication formats regarding nanotechnology in food packaging influence consumer acceptance and perceptions of its risks and benefits?"*

Finally, a promising direction for future research is to evaluate how educational interventions and awareness campaigns influence knowledge, comfort, and trust over time. Longitudinal studies could investigate whether repeated exposure to clear and accessible information, such as through scientific public campaigns or education at supermarkets, results in lasting changes in awareness. A research question for future studies should be: *"To what extent do longitudinal educational interventions and public awareness campaigns lead to sustained improvements in consumer knowledge, comfort, and trust in nanotechnology used in food packaging?"*

**5.5 Conclusion**

As seen earlier by the UN, 795 million people live without food, and around 1 billion are undernourished due to the annual loss of 1.3 billion tons of food. While nanotechnology offers a promising method to reduce food waste, this study shows that consumer awareness of nanotechnology in food packaging remains low, hindering its adoption. The Food Technology Neophobia (FTN) scores among participants ranged from moderate to high, somewhat above global averages. This suggests that neophobia could be a temporary condition rather than a stable consumer trait.

The research question of how we can raise public awareness of nanotechnology in food packaging to reduce food waste has been addressed by this study. Emerging technologies are generally viewed favorably by consumers, who clearly prefer efficient, clear, and understandable

communication via trusted channels. Consumer acceptance depends on trust, and since these are seen as reliable, communication must come from public broadcasters, universities, and independent scientific organizations. In contrast, commercially motivated influencers and messaging are frequently viewed with skepticism. Furthermore, younger consumers are more likely to rely on digital platforms, whereas older consumers favor traditional media. Supermarkets were found to be important communication touchpoints for all groups, and QR codes on packaging were seen as useful resources for offering both concise and comprehensive information.

In addition, this study shows that science communication involves more than just spreading information. It influences how people think, feel, and act. Effective communication creates socially conscious decision-making, increases trust, and reduces uncertainty. A three-step communication model is proposed: scientists introduce the technology, manufacturers explain its use, and consumers access practical information via trusted channels. Furthermore, focusing on functional benefits such as shelf-life extension or sustainability, rather than the term "nanotechnology," could enhance consumer engagement.

This study therefore answers the research question by demonstrating that reducing food waste through nanotechnology is not only a matter of technological progress, but equally a communication challenge. Raising public awareness through short, clear and trustworthy messaging, delivered via preferred channels and framed in terms of tangible benefits, is key to achieving consumer acceptance and unlocking the technology’s full potential.

## AI Statement

During the preparation of this work, the author used Grammarly and ChatGPT to improve the quality of the written text. Grammarly helps with writing and provides suggestions on fluency, grammar, punctuation, and spelling. ChatGPT is an OpenAI chatbot which was used for inspiration, sentence structure, improvement, checking the clarity of paragraphs, and to reduce the number of words. After using these tools, the author reviewed and edited the content as needed and took full responsibility for the content of the work.

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# Appendices

## Appendix A: Ethical approval

UNIVERSITY OF TWENTE.

Dear Mart Janssen,

This is a notification from the Humanities & Social Sciences (HSS) Ethics Committee to inform you that your research project has received a **positive advice.**

| | |
|---|---|
| **Application nr.** | : 250601 |
| **Title** | : Creating Awareness: Nanotechnology in Food Packaging to Address Food Waste |
| **Application date** | : 20-Mar-2025 |
| **Researcher** | : Mart Janssen |
| **Supervisor** | : Joyce Karreman |
| **SONA** | : No |
| **Date of advice** | : 25-Mar-2025 |

The ethics committee has reviewed the ethical aspects of your research project. Based on the information you have provided in the web application, the ethics committee has no major ethical concerns for the research project to go forward as proposed. Please find attached the PDF with the application together with the review comments and advice.

It is your responsibility to ensure that the research is carried out in line with the information provided.

Future communication regarding this research project should also be directed to the secretary of the HSS Ethics Committee via ethicscommittee-hss@utwente.nl, stating the Application nr. 250601.

If you later make considerable changes to the research project that might affect the ethical aspects or raise new ethical concerns, you must submit an amendment. For this, please send a concise description of the intended changes to the secretary of the HSS Ethics Committee, stating the Application nr. 250601. An additional review of the proposed changes will be performed.

Best regards,

Humanities & Social Sciences (HSS) Ethics Committee

**Appendix B1: English protocol focus group for environmentally conscious consumers and for consumers not actively interested in sustainability**

Introduction (duration of 10 minutes)

At the beginning of the session, I will introduce myself as the moderator of this focus group, which will last approximately one and a half hours. I will then mention that we will begin with a round of introductions shortly, but before we do so, we need to take care of an important matter—obtaining informed consent. I will hand out the consent form and first explain the key information verbally (see informed consent statement below). Afterwards, you will have a moment to read through the form yourself, and if there are no questions, I kindly ask you to sign it.

The informed consent statement is as follows:

*Participation in this study is entirely voluntary. You may withdraw from the study at any moment and for any reason, without needing to provide justification. You also have the right to refuse to answer specific questions during the session. This study has been approved by the Ethics Committee of the Faculty of Business and Management Sciences at the University of Twente. The session will be audio recorded to support the analysis. After the session, the recordings will be transcribed and fully anonymized. Once transcription is complete, the transcripts are kept in a safe environment from the University of Twente for five years and the recordings are deleted. All data collected will be handled with strict confidentiality. Anonymized transcripts may be shared only within the research team (the researcher and academic supervisors). The supervisors will not be informed of the identity of participants. Participants have the right to request access to, correction of, or deletion of their personal data at any time. Any quotes used in the final Master thesis will be anonymized to ensure that individuals cannot be identified. If any issues arise during or after participation, you are welcome to contact the researcher, or the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente to discuss a solution.*

After obtaining informed consent, we will proceed with a round of introductions from all participants. Once we have briefly gotten to know one another, I will explain the purpose of the research. At this stage, I will intentionally avoid detailing what nanotechnology in food packaging entails, as this will be a central topic of discussion later in the session.

"Before we begin today's session, I'd like to briefly explain the purpose of this study. This research is part of my master's thesis and aims to explore how awareness about the use of nanotechnology in food packaging can be created among the public. The ultimate goal is to support higher acceptance of this technology, which could contribute to reducing food waste.

This study focuses on how people perceive and respond to new and innovative developments in food packaging. I'm particularly interested in your knowledge, experiences, opinions, and preferences regarding how you receive information about such technologies—especially nanotechnology—including which sources you trust and how this influences your views.

Your input will help improve the way information about these innovations is communicated in the future. For now, we won't go into the technical details—I'd first like to hear your own ideas and associations with the topic. Later in the session, I'll provide a short explanation to support further discussion."

This focus group session will consist of four main topics. After discussing the first two topics, we will take a short break for a restroom visit and coffee or tea. In front of you, you'll find post-its and a pen. For each topic, we will begin with a question to which you will write your answer on a post-it note. I will then place your responses on the flipchart, and we will use these to guide our group discussion. Please feel free to share your opinions openly, and you are also encouraged to respond to the ideas of others. If there are any questions in between, please let me know.

The **first** topic: Nanotechnology knowledge (duration of 15 minutes):

1. On a scale of 1- 10 how positive do you feel about new technologies?"

**Scale:**

1 = Very negative

10 = Very positive

- Let participants write their thoughts on a post-it.
- Stick the post-it on the paper in front of the group.
- Discuss the outcomes of the question.

2. "What do you know about nanotechnology in general?"
- Let's discuss this question together.
- Have you come across the term before? If so, **where** or in **what** context?
- Can you give an example of **where** you think nanotechnology is used?

3. "What do you know about nanotechnology in food packaging?"
- Let's discuss this question together.
- **How** do you think nanotechnology is applied in food packaging?
- **What** functions do you think nanotechnology might have in this context (e.g., freshness, safety, sustainability)?
- Have you ever seen a product that mentions the use of nanotechnology in its packaging?

4. "Where have you received this information?"
- Ask this question in general and discuss the outcomes of the question.

<u>Short introduction of nanotechnology, ways of packaging (IP, AP, SP), and nowadays commercially implemented food packages (duration of 5 minutes):</u>

The moderator will give a brief presentation on nanotechnology, highlighting its promise and applications in food packaging through improved packaging (IP), active packaging (AP), smart packaging (SP), including commercial examples.

The **second** topic: Perceived benefits and risks (duration of 10 minutes):

Each participant will receive **one green post-it** and **one red post-it.** On the green post-it, please write down the **benefits** you perceive when it comes to using nanotechnology in food packaging. On the red post-it, please write down the **risks or concerns** you associate with this technology. Take a few minutes to reflect and write down your thoughts. After everyone is done, we will discuss the answers as a group.

*Let's discuss this question together.*

Additionally, to measure the **neophobia level**, the next question is asked to the participants: "How comfortable are you with the use of new technologies in food production and packaging?"

**Scale:**

1 = Very uncomfortable

10 = Very comfortable

*Let's discuss this question together.*

Break (duration of 10 minutes)

After a maximum of 40 minutes, participants will have the opportunity to grab a small coffee or tea and take a bathroom break. This break was scheduled because we are halfway through, allowing participants to refresh their minds before we continue with the last two topics.

The **third** topic: preferred communication channels & trust in communication providers (duration of 20 minutes):

1. "How do you currently receive information about **new technologies**?"

- Let participants write their thoughts on a post-it.
- Stick the post-it on the paper in front of the group.
- Discuss the outcomes of the question.

2. "Do you trust (online) providers giving information about **new technologies**, if yes **who** do you trust to share this information?"

- Let's discuss this question together.
- If yes, in **what** context, **why**, and **who**?
- If not, **why** do you not trust them?

3. "Who do you trust to provide accurate information about **nano packaging**?"

- Let's discuss this question together.
- Also, provide information about **why** you trust them.

4. "Where would you prefer to receive information about **nano packaging**?"

- Let's discuss this question together.

- Explain also **why** you want to receive this information on the specific channels.

5. “In which way would you prefer to receive information about **nano packaging** (for e.g. an infographic, video, photo, just information etc.)?”
   - Let’s discuss this question together.
   - Explain also **why** you want to receive this information in this way.

The **fourth** topic: participants' likelihood of purchasing products packaged using nanotechnology (duration of 10 minutes):

1. “With the knowledge you have now gained, how likely are you to buy a packaged product that contains nanotechnology?

   **Scale:**
   1 = Very unlikely
   10 = Very likely

   - Let’s discuss this question together.
   - Explain **why** you assigned this grade based on the likelihood of purchasing a packaged product made with nanotechnology.

Closing (duration of 5 minutes):

After discussing all the topics, the focus group will end. The moderator will request feedback from the participants before giving a word of thanks. Then, the focus group will be finished.

**Appendix B2: Nederlands protocol focusgroep voor milieubewuste consumenten en voor consumenten die niet actief geïnteresseerd zijn in duurzaamheid**

Inleiding (duur van 10 minuten):

Aan het begin van de sessie zal ik mezelf voorstellen als moderator van deze focusgroep, die ongeveer anderhalf uur zal duren. Ik zal dan zeggen dat we dadelijk zullen beginnen met een voorstelronde, maar voor we dat doen, moeten we eerst een belangrijke zaak regelen: het verkrijgen van geïnformeerde toestemming. Ik zal het toestemmingsformulier uitdelen en eerst de belangrijkste informatie mondeling toelichten (zie de toestemmingsverklaring hieronder). Daarna heb je even de tijd om het formulier zelf door te lezen en als er geen vragen zijn, vraag ik je vriendelijk om het te ondertekenen. Daarnaast wil ik graag weten of u het prettig vindt dat ik u of je aanspreek.

**De geïnformeerde toestemmingsverklaring luidt als volgt:**

*Deelname aan dit onderzoek is geheel vrijwillig. U kunt zich op elk moment en om elke reden terugtrekken uit het onderzoek, zonder dat u hiervoor een reden hoeft op te geven. U hebt ook het recht om specifieke vragen te weigeren tijdens de sessie. Dit onderzoek is goedgekeurd door de Ethische Commissie van de Faculteit gedrags-, management en sociale wetenschappen van de Universiteit Twente. De sessie wordt opgenomen ter ondersteuning van de analyse. Na de sessie worden de opnames getranscribeerd en volledig geanonimiseerd. Zodra de transcriptie is voltooid worden de transcripten bewaard in een veilige omgeving van de Universiteit Twente voor vijf jaar en worden de opnames verwijderd. Alle verzamelde gegevens worden strikt vertrouwelijk behandeld. Geanonimiseerde transcripties mogen alleen gedeeld worden binnen het onderzoeksteam (de onderzoeker en academische begeleiders). De begeleiders worden niet geïnformeerd over de identiteit van de deelnemers. Deelnemers hebben te allen tijde het recht om inzage in, correctie van of verwijdering van hun persoonlijke gegevens aan te vragen. Alle citaten die worden gebruikt in de uiteindelijke Master thesis zullen worden geanonimiseerd om ervoor te zorgen dat individuen niet kunnen worden geïdentificeerd. Als er problemen ontstaan tijdens of na deelname, kunt u contact opnemen met de onderzoeker of de secretaris van de*

*Commissie Ethiek/domein Humanities & Social Sciences van de faculteit gedrags-, management en sociale wetenschappen van de Universiteit Twente om een oplossing te bespreken.*

Na het verkrijgen van geïnformeerde toestemming, gaan we verder met een voorstelronde van alle deelnemers. Nadat we elkaar kort hebben leren kennen, leg ik het doel van het onderzoek uit. In dit stadium zal ik bewust niet in detail treden over wat nanotechnologie in voedselverpakkingen inhoudt, omdat dit later in de sessie een centraal onderwerp van discussie zal zijn.

"Voordat we met de sessie van vandaag beginnen, wil ik graag kort het doel van dit onderzoek uitleggen. Dit onderzoek maakt deel uit van mijn masterscriptie en heeft als doel om te onderzoeken hoe bewustzijn over het gebruik van nanotechnologie in voedselverpakkingen kan worden gecreëerd bij het publiek. Het uiteindelijke doel is om een hogere acceptatie van deze technologie te ontwikkelen, wat bij zou dragen aan het verminderen van voedselverspilling.

Dit onderzoek richt zich op hoe mensen nieuwe en innovatieve ontwikkelingen in voedselverpakkingen waarnemen en hierop reageren. Ik ben vooral geïnteresseerd in uw kennis, ervaringen, meningen en voorkeuren met betrekking tot de manier waarop u informatie ontvangt over dergelijke technologieën - met name nanotechnologie - inclusief welke bronnen u vertrouwt en hoe dit uw mening beïnvloedt.

Uw input zal helpen om de manier waarop informatie over deze innovaties in de toekomst wordt gecommuniceerd te verbeteren. Voorlopig gaan we niet in op de technische details - ik wil eerst jullie eigen ideeën en associaties met het onderwerp horen. Later in de sessie zal ik een korte uitleg geven ter ondersteuning van verdere discussie."

Deze focusgroepsessie zal bestaan uit vier hoofdonderwerpen. Na het bespreken van de eerste twee onderwerpen nemen we een korte pauze voor een toiletbezoek en koffie of thee. Voor je liggen post-its en een pen. Voor elk onderwerp beginnen we met een vraag waarop jullie je antwoord op een post-it schrijven. Daarna zet ik jullie antwoorden op de flip-over en aan de hand daarvan gaan we in groep discussiëren. Voel je vrij om je mening openlijk te delen en je wordt ook aangemoedigd om te reageren op de ideeën van anderen. Als er tussendoor nog vragen zijn, laat het me dan weten.

Het **eerste** onderwerp: Kennis over nanotechnologie (duur 15 minuten):

1. Op een schaal van 1- 10 hoe positief sta je tegenover nieuwe technologieën?"

   **Schaal:**

   1 = Zeer negatief

   10 = zeer positief

   - Laat de deelnemers hun gedachten op post-its schrijven.
   - Plak de post-it op het papier voor de groep.
   - Bespreek de uitkomsten van de vraag.

2. "Wat weet je over nanotechnologie in het algemeen?"
   - Laten we deze vraag samen bespreken.
   - Ben je de term al eerder tegengekomen? Zo ja, waar of in welke context?
   - Kun je een voorbeeld geven van waar je denkt dat nanotechnologie wordt gebruikt?

3. "Wat weet je over nanotechnologie in voedselverpakkingen?"
   - Laten we deze vraag samen bespreken.
   - Hoe denk je dat nanotechnologie wordt toegepast in voedselverpakkingen?
   - Welke functies zou nanotechnologie in deze context kunnen hebben (bijv. versheid, veiligheid, duurzaamheid)?
   - Heb je ooit een product gezien waarvan de verpakking melding maakt van het gebruik van nanotechnologie?

4. “Waar heb je deze informatie vandaan?”
    - Stel deze vraag in het algemeen en bespreek de uitkomsten van de vraag.

Korte introductie van nanotechnologie, manieren van verpakken (IP, AP, SP) en tegenwoordig commercieel geïmplementeerde voedselverpakkingen (duur van 5 minuten):

De moderator geeft een korte presentatie over nanotechnologie en belicht de belofte en toepassingen ervan in voedselverpakkingen via verbeterde verpakking (IP), actieve verpakking (AP), slimme verpakking (SP), uit inclusief commerciële voorbeelden.

Het **tweede** onderwerp: Waargenomen voordelen en risico's (duur van 10 minuten):

Elke deelnemer ontvangt een groene post-it en een rode post-it. Schrijf op de groene post-it de voordelen op die u ziet bij het gebruik van nanotechnologie in voedselverpakkingen. Schrijf op de rode post-it de risico's of zorgen die je associeert met deze technologie. Neem een paar minuten de tijd om na te denken en je gedachten op te schrijven. Als iedereen klaar is, bespreken we de antwoorden als groep.

*Let’s discuss this question together.*

Om het neofobie-niveau te meten, wordt de volgende vraag aan de deelnemers gesteld: “Hoe comfortabel voel je je met het gebruik van nieuwe technologieën in voedselproductie en verpakking?”

**Schaal:**
1 = zeer ongemakkelijk
10 = zeer comfortabel

*Laten we deze vraag samen bespreken.*

Pauze (duur 10 minuten)

Na maximaal 40 minuten krijgen de deelnemers de gelegenheid om een kopje koffie of thee te drinken en een toiletpauze te nemen. Deze pauze is gepland omdat we halverwege zijn, zodat deelnemers hun gedachten kunnen opfrissen voordat we verder gaan met de laatste twee onderwerpen.

Het **derde** onderwerp: voorkeurscommunicatiekanalen & vertrouwen in communicatieaanbieders (duur van 20 minuten):

1. "Hoe ontvang je momenteel informatie over nieuwe technologieën?"
    - Laat de deelnemers hun gedachten op post-its schrijven.
    - Plak de post-its op het papier voor de groep.
    - Bespreek de uitkomsten van de vraag.

2. "Vertrouw je (online) aanbieders die informatie geven over nieuwe technologieën, zo ja wie vertrouw je om deze informatie te delen?"
    - Laten we deze vraag samen bespreken.
    - Zo ja, in welke context, waarom en wie?
    - Zo nee, waarom vertrouw je ze niet?

3. "Wie vertrouw je om accurate informatie te geven over nano-verpakkingen?"
    - Laten we deze vraag samen bespreken.
    - Als je de keuze hebt, wie vertrouw je dan om u accurate informatie te geven over nano-verpakkingen?
    - Geef ook informatie over waarom u hen vertrouwt.

4. “Waar ontvang je het liefst informatie over nano-verpakkingen?”
    - Laten we deze vraag samen bespreken.
    - Leg uit waar je informatie over nano-verpakkingen wilt ontvangen.
    - Leg ook uit waarom je deze informatie op de specifieke kanalen wilt ontvangen.

5. “Op welke manier zou je het liefst informatie over nano-verpakkingen ontvangen (bijvoorbeeld een infographic, video, foto, gewoon informatie etc.)?”
    - Laten we deze vraag samen bespreken.
    - Leg uit op welke manier je informatie over nano-verpakkingen wilt ontvangen.
    - Leg ook uit waarom je deze informatie op deze manier wilt ontvangen.

Het **vierde** onderwerp: de waarschijnlijkheid dat deelnemers producten kopen die verpakt zijn met behulp van nanotechnologie (duur 10 minuten):

“Met de kennis die u nu hebt opgedaan, hoe waarschijnlijk is het dat je een verpakt product koopt dat nanotechnologie bevat?”

**Schaal:**

1 = Zeer onwaarschijnlijk

10 = Zeer waarschijnlijk

Laten we deze vraag samen bespreken.

Leg uit waarom je dit cijfer hebt gegeven op basis van de waarschijnlijkheid dat je een verpakt product koopt dat gemaakt is met nanotechnologie.

Afsluiting (duur 5 minuten):

Na het bespreken van alle onderwerpen eindigt de focusgroep. De moderator zal de deelnemers om feedback vragen voordat hij een dankwoord uitspreekt. Daarna wordt de focusgroep beëindigd.

**Appendix C: Dutch protocol for interviews with experts in the fields of nanotechnology and (food) packaging**

**<u>Inleiding (duur van 10 minuten):</u>**

Aan het begin van de sessie zal ik aangeven dat het interview wordt opgenomen, mits daarvoor vooraf toestemming is gegeven (ethical approval). Daarna stel ik mezelf kort voor en vraag ik de geïnterviewde hetzelfde te doen, met daarbij een toelichting op zijn of haar werkzaamheden. Vervolgens geef ik aan hoelang het interview ongeveer zal duren en licht ik kort het doel van het onderzoek en dit gesprek toe.

**Doel van het onderzoek**

Dit interview maakt deel uit van mijn masterscriptie en richt zich op het gebruik van **nanotechnologie in voedselverpakkingen**. Het centrale doel van het onderzoek is om te begrijpen hoe bewustzijn hierover kan worden vergroot bij consumenten, met als uiteindelijk doel een bredere maatschappelijke acceptatie van deze technologie. Een grotere acceptatie kan op termijn bijdragen aan het verminderen van voedselverspilling.

In het onderzoek staat centraal hoe mensen innovatieve technologieën in voedselverpakkingen waarnemen en beoordelen. Ik ben met name geïnteresseerd in hun kennis, ervaringen, meningen en voorkeuren met betrekking over hoe zij geïnformeerd willen worden. Denk hierbij aan communicatiekanalen, de mate van vertrouwen in informatiebronnen, en hoe deze factoren hun houding beïnvloeden ten aanzien van nanotechnologie.

Tot nu toe heb ik vier focusgroepen gehouden met consumenten: zowel mensen die actief bezig zijn met duurzaamheid als mensen voor wie dat minder speelt. Ik ben nu benieuwd hoe experts uit het veld van nanotechnologie en/of de voedselverpakkingsindustrie aankijken tegen de resultaten van deze focusgroepen.

De focusgroepen waren opgebouwd rond vier hoofdonderwerpen:

- Kennis over nanotechnologie
- Waargenomen risico’s en voordelen

- Voorkeurskanalen en vertrouwen in informatiebronnen
- Verwachte bereidheid om voedsel met nanotechnologische verpakking te kopen

**Doel van dit interview**

Het doel van dit gesprek is daarom tweeledig:

1. Achterhalen in hoeverre u bekend bent met nanotechnologie in voedselverpakkingen;
2. Uw mening horen over op welke manier het bewustzijn van consumenten over nanotechnologie in voedselverpakkingen vergroot kan worden.

**Vragen (10 minuten):**

Ik heb u gevraagd voor dit interview ten aanzien van uw expertise of vakgebied. Ik zou daarom eerst een aantal korte vragen met u willen doornemen en daarna ben ik benieuwd hoe u tegen de resultaten van de focusgroepen aankijkt.

1. Hoe staat u tegenover nieuwe technologieën?
2. Wat weet u over nanotechnologie in het algemeen?
3. Wat weet u over voedselverpakkingen?
4. Wat weet u over nanotechnologie in voedselverpakkingen?
5. Hoe komt u aan deze kennis?

**Resultaten focusgroepen (40 minuten):**

1. **Houding t.o.v. nieuwe technologie algemeen:**

- Over het algemeen zeer positief (8-10) tot positief met kanttekening (4-7)
    - Kanttekening: ethische aspect, menselijkheid moet blijven, moeten we wel blijven door ontwikkelen, hoever gaan we met AI, toch ook veel respondenten die kritisch en of bang zijn.

**! Vraag aan respondent:** Veel consumenten zijn enerzijds positief, maar maken zich ook zorgen over de ethiek en grenzen van technologie. Herkent u dit beeld, of ziet u in uw praktijk een ander sentiment? Wat is volgens u nodig om deze twijfels of angsten te verkleinen?

2. **Kennisniveau nanotechnologie algemeen:**

- Weinig tot geen kennis
- Als ze kennis hebben dan gaat dat over kennis buiten voedselverpakkingen en dan vooral over chips of medicijnen
- Waarbij ze het over het algemeen niet kunnen herinneren waar ze ooit die informatie hebben gehoord of gelezen

**Kennisniveau nanotechnologie voedselverpakkingen:**

- Weinig tot geen kennis
- Vervolgens met gokjes komen ze een beetje in de buurt maar alles is wel met een vraagteken

**! Vraag aan respondent:** De meeste consumenten weten weinig tot niets over nanotechnologie in voedselverpakkingen. Herkent u dat consumenten vaak weinig weten over nanotechnologie, zeker in de context van voedsel? Wat zegt dit volgens u over hoe deze technologie tot nu toe is gecommuniceerd?

3. **Zorgen en nadelen nanotechnologie:**

- Er zijn zorgen over de lange termijn effecten van nanotechnologie in voedselverpakkingen, de duurzaamheid van de verpakkingen en de praktische haalbaarheid, zoals de kosten en de verwerking van afval. Consumenten vragen zich ook af of ze deze technologie wel zullen vertrouwen en vervolgens accepteren, en of het een invloed heeft op hun gedrag. Daarnaast is er bezorgdheid over de veiligheid van nanotechnologie in voedselverpakkingen, vooral of het risico op gezondheidseffecten groot is.

**! Vraag aan respondent:** Welke van deze zorgen vindt u zelf het meest terecht of begrijpelijk, en welke zorgen verdienen volgens u prioriteit in communicatie en waarom? En hoe kunnen we consumenten helpen vertrouwen te krijgen in nanotechnologie in verpakkingen?

4. **Voordelen nanotechnologie:**

- Minder voedselverspilling
- Milieuvoordelen
- Gebruiksgemak en praktische efficiëntie
- Gezondheid en veiligheid
- Kostenbesparing en economische voordelen

**! Vraag aan respondent:** Hoe denkt u dat we deze voordelen op een geloofwaardige en toegankelijke manier onder de aandacht kunnen brengen, zonder dat het als 'marketing' overkomt?

5. **Comfort (hoe comfortabel voelt men zich met voedseltechnologie) voedseltechnologie:**

- Twijfel comfort (4-7) - 16
- Hoge comfort (8-10) - 13
- Lage comfort (1-3) - 2
- Waar ze onzeker over zijn of twijfels bij hebben is:
  - Gebrek aan kennis en dat zorgt voor onzekerheid
  - Vertrouwen in regelgeving

**! Vraag aan respondent:** Twijfels bij consumenten lijken vooral voort te komen uit onduidelijkheid over regelgeving en kennis. Wat zou u als expert belangrijk vinden om te communiceren om comfort en vertrouwen te vergroten?

6. **Huidige informatiekanalen nieuwe technologie:**

- Social media en platforms (44):
    - LinkedIn (7)
    - Streamingsdiensten (7)
    - Overig en onbekend (algemene term social media)
    - Instagram weinig (3) en TikTok ook weinig (4)
- Traditionele media & nieuws (21)
- Persoonlijk netwerk (13)

**! Vraag aan respondent:** Consumenten noemen uiteenlopende kanalen, maar weten vaak niet waar hun informatie precies vandaan komt. Wat zegt dit volgens u over de informatievoorziening rondom technologische innovaties? Welke kanalen zijn volgens u goed voor het informeren over nanotechnologie in voedselverpakkingen?

7. **Vertrouwen in informatieverschaffers:**

- Wetenschap en onafhankelijken
    - Onafhankelijke wetenschappers en instituten
    - Mensen die zelf de onderzoeken doen
    - Universiteiten
    - Wetenschappelijk onderzoek
    - Voedsel en Waren Autoriteit
- Overheid en publieke omroepen
    - NOS
    - Overheid publicaties
- Experts en publieke figuren die in die niche zitten kunnen ze waarderen
- Daarnaast hangt de betrouwbaarheid af van het medium/platform en krijgen ze wantrouwen door commerciële belangen, daarnaast vinden ze de presentatie en herhaling erg belangrijk.

**! Vraag aan respondent:** Consumenten geven aan vooral onafhankelijke wetenschappers en instituten te vertrouwen. Is dat ook uw ervaring? En wat is volgens u de rol van wetenschappers

en universiteiten in het communiceren van dit soort technologie, en hoe voorkomen we dat het vertrouwen beschadigd raakt door bijvoorbeeld commerciële samenwerkingen?

8. **Voorkeurskanalen informatie nanoverpakkingen:**

- Traditionele media (TV/krant)
- Online & Social Media
- Informatie in supermarkt (op product of fysiek)

**Presentatie nano-informatie:**

- Consumenten geven aan dat communicatie over nanotechnologie kort, duidelijk en laagdrempelig moet zijn, met zowel voor- als nadelen op een objectieve manier gepresenteerd. Toegankelijkheid is belangrijk, bijvoorbeeld via duidelijke verwijzingen naar extra informatie in de supermarkt, zoals op de verpakking of via online kanalen. De presentatie moet aantrekkelijk zijn, zonder een commerciële uitstraling, en vertrouwen wordt gewekt door bronvermelding; daarnaast is visuele en audiovisuele communicatie de voorkeur, met differentiatie per doelgroep (bijvoorbeeld ouderen vs. jongeren).

**! Vraag aan respondent:** Hoe zou u zelf idealiter communiceren over nanotechnologie in verpakkingen? Wat zijn volgens u belangrijke voorwaarden voor goede, geloofwaardige voorlichting?

9. **Aankoopintentie nanoverpakkingen;**

- Hoge intentie (8-10) - 21
- Twijfelende intentie (4-7) - 12
- Lage intentie (1-3) - 6
- Voorwaardelijk vertrouwen:
    - Informatievoorziening of uitleg
    - Prijs
    - Toepassing of verpakkingstype

  - Vertrouwen in bron

**Betalingsbereidheid:**

- On voorwaardelijk ja - 2
- Voorwaardelijk ja – 14
  - Hangt van de prijs af
  - Productafhankelijk
  - Als ze het voordeel ervan kunnen ervaren
  - Situatie afhankelijk
- Nee of beperkt ja – 1
- Voorwaardelijk ja:
  - Betaalbaarheid
  - Producttype
  - Verspilling/voordeel

**! Vraag aan respondent:** Hoe kijkt u aan tegen deze voorwaardelijke aankoopintentie? Wat zou volgens u het verschil kunnen maken tussen twijfel en daadwerkelijke aankoop?

**Appendix D: Selection criteria for focus group and interview participants**

**General selection criteria for all groups:**

- **Age range:** 18+ (to ensure informed participation)
- **Geographic location:** ideally from the Enschede area
- **No prior deep knowledge of nanotechnology** (except for group 3)

**1. Environmental conscious groups**

**Defining characteristics:**

- Actively engaged in sustainability-related behaviors (e.g., choosing eco-friendly packaging of bags, following sustainability news, or participating in green initiatives)
- Interested in reducing food waste or supporting circular economy efforts

**How to identify them:**

- Shopping habits: prefers organic, biodegradable, or sustainable food (packaging)
- Membership in sustainability communities (e.g. zero-waste groups)
- Expresses concern about climate change, pollution, and food waste

**Questions to possibly ask on forehand:**

- Do you actively seek out environmentally friendly packaging when shopping? (yes/no)
- How important is sustainability in your food purchasing decisions? (scale 1-10)
- Have you ever participated in sustainability-focused programs, forums, or discussions? (yes/no)

**2. Consumers not actively interested in sustainability**

**Defining characteristics:**

- Little to no interest in sustainability as a primary motivator for purchasing food
- Makes choices based on convenience, cost, brand loyalty, or other personal preferences rather than eco-friendliness
- Likely to have less awareness of nanotechnology in food packaging

**How to identify them:**

- Prioritizes cost and convenience over sustainability
- Unlikely to seek out eco-friendly alternatives
- Unaware of sustainability certifications or initiatives

**Questions to ask on forehand:**

- How often do you choose sustainable food (packaging) (rarely/sometimes/often)
- When buying packaged food, what is your biggest concern? (price, brand, taste, sustainability)
- Have you ever deliberately avoided plastic packaging for sustainability reasons (yes/no)

**3. (Young) experts and students in agri-food & related fields**

**Defining characteristics:**

- Background in agriculture, food technology, industrial design, packaging innovation, or a related field
- Likely to have academic or professional knowledge of food production and technology
- Can provide expert insights on risks and benefits, regulations, technical challenges or other related aspects

**How to identify them:**

- Enrolled in or graduated from relevant study programs (e.g., Food Science, Agri-Tech, Industrial Design, Environmental Science)
- Working in food production, food safety, innovation, packaging etc.
- Follows scientific/technical discussions on packaging innovations

**Questions to ask on forehand:**

- What is your field of study or work?
- How familiar are you with food packaging technologies? (Not at all/Familiar/Expert)
- Have you worked on any projects related to food or packaging innovation or sustainability? (Yes/No)

**Appendix E1: English information sheet and informed consent about the study 'Creating Awareness: Nanotechnology in Food Packaging to Address Food Waste'**

This research project aims to investigate how to create awareness of the application of nanotechnology in food packaging among the public. The research is conducted by Mart Janssen, a Master student in Communication Science at the University of Twente. The study is supervised by Dr. Joyce Karreman and Dr. T.J.L. van Rompay. The research is reviewed and approved by the BMS Ethics Committee.

The research consists of qualitative focus groups in which its purpose must identify the public's nanotechnology knowledge level, perceived risks and benefits, preferred communication channels, neophobia level, and the trust level in communication providers. The focus groups will last around 90 minutes.

Participation in the research is entirely voluntary. Participants can withdraw from the study at any time for any reason, without the need to justify their decision. Participants also have the right to refuse to answer specific questions.

The researchers would like to make an audio recording of the interview. After the interview, the recording will be transcribed and anonymized. When the transcription is made, the recording will be erased.

The data will be saved as anonymized transcripts and may be accessed within the research team (the researchers and the supervisors). The supervisors do not know with whom the focus groups were held. Participants have the right to request access to and rectification or erasure of their focus group data. The transcripts will be stored in a safe online environment of the University of Twente for a period of five years.

The data will be used by the researcher to write their Master theses. If quotes from participants are used, special attention will be paid to the confidentiality of the research. Only quotes that cannot be reduced to individuals can be used in the reporting.

In the case of questions, suggestions, or concerns, please feel free to contact the researchers or their supervisors (see emails below).

Researchers

Mart Janssen (m.h.janssen@student.utwente.nl)

Supervisors

Joyce Karreman (j.karreman@utwente.nl)

Thomas van Rompay (t.j.l.vanrompay@utwente.nl)

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee- hss@utwente.nl

**Informed consent form for the study 'Creating Awareness: Nanotechnology in Food Packaging to Address Food Waste'.**

**You will be given a copy of the study information and this form.**

| *Please tick the appropriate boxes* | **Yes** | **No** |
|---|---|---|
| **Taking part in the study** | | |
| I have read and understood the study information. I have been able to ask questions about the study and my questions have been answered to my satisfaction. | □ | □ |
| I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions, and I can withdraw from the study at any time, without having to give a reason. | □ | □ |
| **Use of the information in the study** | | |
| I understand that the information I provide will be used for this master theses. | □ | □ |
| I understand that personal information collected about me that can identify me, such as my name or my job function, will not be shared beyond the study team. | □ | □ |
| I agree that my anonymized focus group fragments can be quoted in research output. I agree to be audio recorded. | □ | □ |

**Signatures**

| _____ | _____ | _____ |
|---|---|---|
| Name of participant | Signature | Date |

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

| _____ | _____ | _____ |
|---|---|---|
| Name of the Researcher [printed] | Signature [printed] | Date |

**Appendix E2: Nederlands informatieblad en geïnformeerde toestemming over het onderzoek 'Bewustwording creëren: Nanotechnologie in voedselverpakkingen om voedselverspilling tegen te gaan'**

Dit onderzoeksproject heeft als doel om te onderzoeken hoe het publiek bewust gemaakt kan worden van de toepassing van nanotechnologie in voedselverpakkingen. Het onderzoek wordt uitgevoerd door Mart Janssen, masterstudent Communicatiewetenschap aan de Universiteit Twente. Het onderzoek wordt begeleid door Dr. Joyce Karreman en Dr. T.J.L. van Rompay. Het onderzoek is beoordeeld en goedgekeurd door de ethische commissie van BMS.

Het onderzoek bestaat uit kwalitatieve focusgroepen met als doel het identificeren van het kennisniveau over nanotechnologie bij het publiek, de waargenomen risico's en voordelen, de voorkeurscommunicatiekanalen, het neofobie-niveau en het vertrouwensniveau in communicatieverstrekkers. De focusgroepen duren ongeveer 90 minuten.

Deelname aan het onderzoek is geheel vrijwillig. Deelnemers kunnen zich op elk moment om welke reden dan ook terugtrekken uit het onderzoek, zonder dat ze hun beslissing hoeven te rechtvaardigen. Deelnemers hebben ook het recht om te weigeren specifieke vragen te beantwoorden.

De onderzoeker wil graag een audio-opname maken van de focusgroep. Na de focusgroep wordt de opname getranscribeerd en geanonimiseerd. Als de transcriptie is gemaakt, wordt de opname gewist.

De gegevens worden opgeslagen als geanonimiseerde transcripties en zijn toegankelijk binnen het onderzoeksteam (de onderzoeker en de begeleiders). De begeleiders weten niet met wie de focusgroepen zijn gehouden. Deelnemers hebben het recht om inzage in en rectificatie of verwijdering van hun focusgroep gegevens te vragen. De transcripties worden opgeslagen in een veilige online omgeving van de Universiteit Twente voor een periode van vijf jaar.

De gegevens worden door de onderzoeker gebruikt voor het schrijven van de masterscriptie. Als citaten van deelnemers worden gebruikt, wordt speciale aandacht besteed aan de

vertrouwelijkheid van het onderzoek. Alleen citaten die niet herleid kunnen worden tot individuen kunnen gebruikt worden in de rapportage.

Als u vragen, suggesties of zorgen hebt, kunt u contact opnemen met de onderzoeker of de begeleiders (zie onderstaande e-mails).

Onderzoeker

Mart Janssen (m.h.janssen@student.utwente.nl)

Begeleiders

Joyce Karreman (j.karreman@utwente.nl)

Thomas van Rompay (t.j.l.vanrompay@utwente.nl)

Als u vragen heeft over uw rechten als onderzoek deelnemer of als u informatie wilt inwinnen, vragen wilt stellen of zorgen over dit onderzoek wilt bespreken met iemand anders dan de onderzoeker en begeleiders, neem dan contact op met de secretaris van de Commissie Ethiek/domein Humanities & Social Sciences van de faculteit gedrags-, management en sociale wetenschappen van de Universiteit Twente via ethische commissie- hss@utwente.nl.

**Toestemmingsformulier voor het onderzoek 'Bewustwording creëren: Nanotechnologie in voedselverpakkingen om voedselverspilling tegen te gaan'.**

**U krijgt een kopie van dit formulier.**

| *Vink de juiste vakjes aan* | **Ja** | **Nee** |
|---|---|---|
| **Deelnemen aan het onderzoek** | | |
| Ik heb de studie-informatie gelezen en begrepen. Ik heb vragen kunnen stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord. | □ | □ |
| Ik geef vrijwillig toestemming om deel te nemen aan dit onderzoek en begrijp dat ik kan weigeren vragen te beantwoorden, en dat ik mij op elk moment uit het onderzoek kan terugtrekken, zonder opgaaf van reden. | □ | □ |
| **Gebruik van de informatie in het onderzoek** | | |
| Ik begrijp dat de informatie die ik geef, gebruikt zal worden voor deze masterscriptie. | □ | □ |
| Ik begrijp dat over mij verzamelde persoonlijke informatie die mij kan identificeren, zoals mijn naam of mijn functie, niet buiten het onderzoeksteam zal worden gedeeld. | □ | □ |
| Ik ga ermee akkoord dat mijn geanonimiseerde interviewfragmenten geciteerd mogen worden gebruikt in de onderzoeks output. En ik ga akkoord met geluidsopnames. | □ | □ |

**Handtekeningen**

| _____ | _____ | _____ |
|---|---|---|
| Naam deelnemer | Handtekening | Datum |

Ik heb het informatieblad nauwkeurig voorgelezen aan de potentiële deelnemer en er naar mijn beste vermogen voor gezorgd dat de deelnemer begrijpt waarmee hij of zij vrijwillig instemt.

| _____ | _____ | _____ |
|---|---|---|
| Naam van de onderzoeker [geprint] | Handtekening [geprint] | Datum |

**Appendix F: Dutch presentation sheets focus groups**


# INTRODUCTIE

- VOORSTELRONDE
- UITLEG ONDERZOEK & DOEL VAN VANDAAG
- PLANNING FOCUSGROEP

UNIVERSITY OF TWENTE.

# ONDERDEEL 1

"OP EEN SCHAAL VAN 1- 10 HOE POSITIEF STA JE TEGENOVER NIEUWE TECHNOLOGIEËN?"

1 = ZEER NEGATIEF

10 = ZEER POSITIEF

## WAT IS NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN?

NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN MAAKT GEBRUIK VAN EXTREEM KLEINE MATERIALEN DIE KLEINER ZIJN DAN **100 NANOMETER**.

VERGELIJKING: 1 NANOMETER IS EEN MILJOENSTE VAN EEN MILLIMETER.

DEZE NANOMATERIALEN KUNNEN ZOWEL **ORGANISCH** (BIJVOORBEELD CELLULOSE, EN MATERIALEN OP BASIS VAN VETTEN OF EIWITTEN), ALS **ANORGANISCH** (ZOALS ZILVER, TITANIUM, ZINK) OF EEN COMBINATIE VAN BEIDE ZIJN.

UNIVERSITY OF TWENTE.

## WAT IS NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN?

UNIVERSITY OF TWENTE.

# WAT IS NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN?

**1. Improved packaging**

Incorporatie van nanomaterialen voor:

1. Gasbarrière
2. Temperatuurbestendigheid
3. Vochtbestendigheid

**2. Active packaging**

Incorporatie van nanomaterialen voor:

1. Inactivering van ziekteverwekkers
2. De houdbaarheid verlengen
3. De voedselveiligheid verhogen

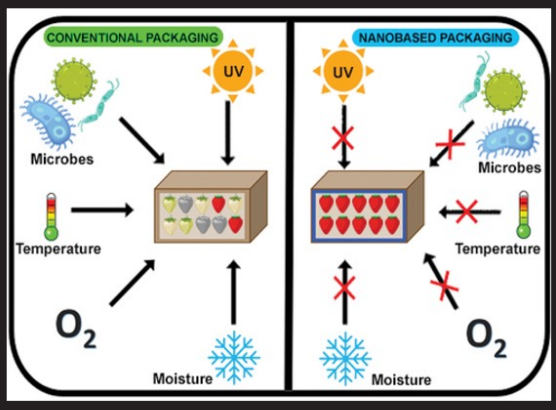

**3. Intelligent packaging**

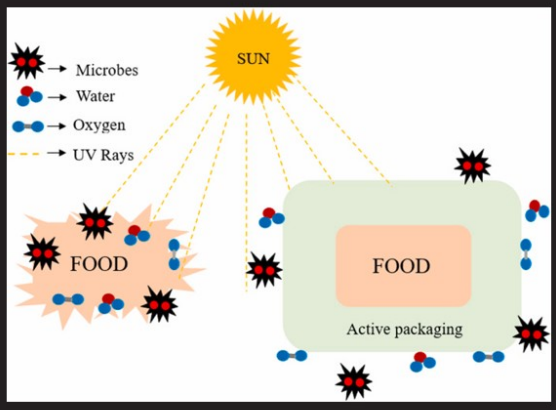
Incorporatie van nanomaterialen voor:

1. Herkenning van bederf
2. Herkenning van ziekteverwekkers
3. Monitoring van voedselkwaliteit

UNIVERSITY OF TWENTE.

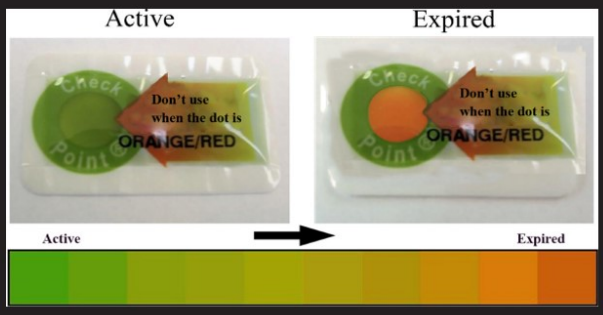
# WAT IS NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN?




UNIVERSITY OF TWENTE.

# WAT IS NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN?





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## ONDERDEEL 2

**GROENE POST-IT: NOTEER DE** VOORDELEN DIE JE ZIET VAN NANOTECHNOLOGIE IN VOEDSELVERPAKKINGEN.

**ROZE POST-IT:** NOTEER DE RISICO'S OF ZORGEN DIE JE HIERBIJ HEBT.


## ONDERDEEL 2

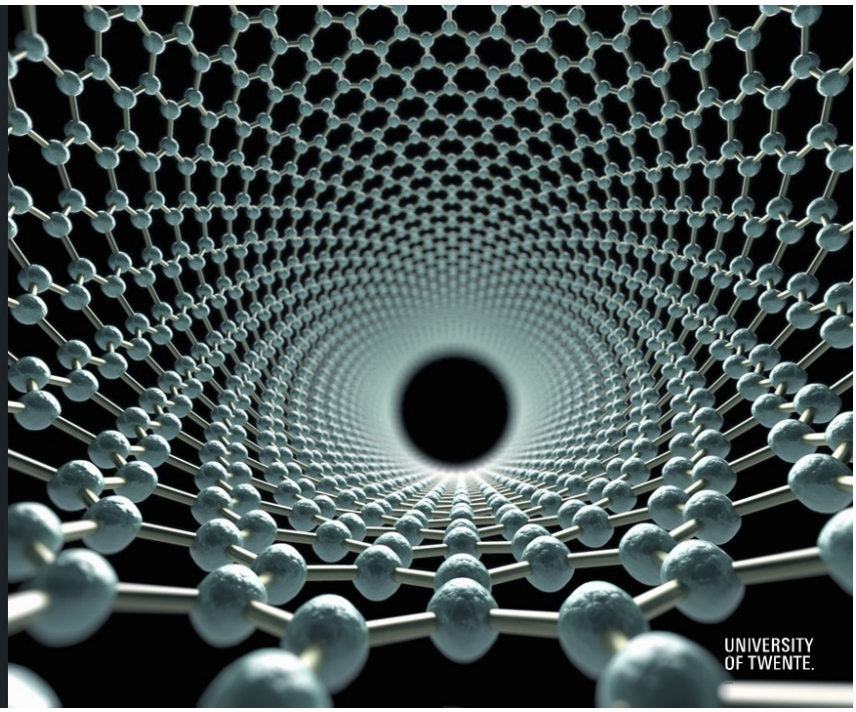
"HOE COMFORTABEL VOEL JE JE MET HET GEBRUIK VAN NIEUWE TECHNOLOGIEËN IN VOEDSELPRODUCTIE EN VERPAKKING?"

1 = ZEER ONGEMAKKELIJK

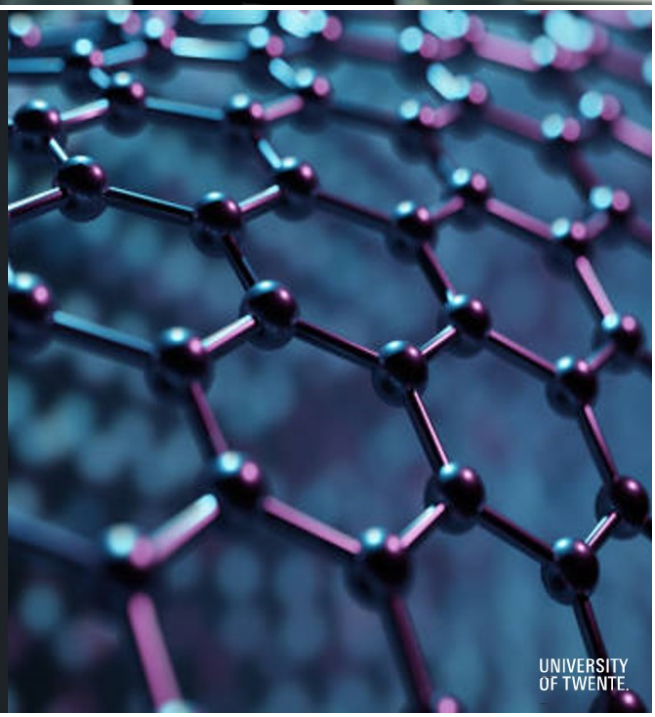
10 = ZEER COMFORTABEL

## PAUZE

*5 MIN.*




## VRAGEN/OPMERKINGEN?



## ONDERDEEL 3

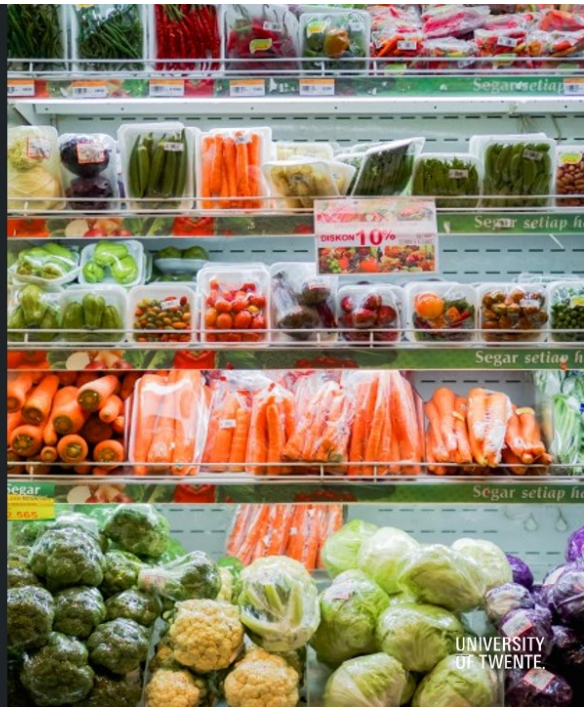
”HOE ONTVANG JE MOMENTEEL INFORMATIE OVER NIEUWE TECHNOLOGIEËN?”


## ONDERDEEL 4

”MET DE KENNIS DIE JE NU HEBT OPGEDAAN, HOE WAARSCHIJNLIJK IS HET DAT JE HET AANDURFT OM EEN VERPAKT VOEDINGSPRODUCT TE KOPEN DAT NANOTECHNOLOGIE BEVAT?”

1 = ZEER ONWAARSCHIJNLIJK

10 = ZEER WAARSCHIJNLIJK



## BIJ TIJD OVER

”ZOU JE BEREID ZIJN MEER TE BETALEN VOOR VOEDSEL VERPAKT MET NANOTECHNOLOGIE?"


## AFSLUITING

UNIVERSITY
OF TWENTE.


BEDANKT VOOR JULLIE DEELNAME
UNIVERSITY
OF TWENTE.

**Appendix G: Commercially available nano-based packaging material examples**

**Table 1.**

*Examples of commercially available nano-based food packaging materials and their functions*

| Material type | Form | Application Product | Function | Brand and company |
|---|---|---|---|---|
| Nylon 6-nanoclay composite | Barrier nylon resins | Beer and flavored alcoholic beverage bottles, PET | Oxygen scavenging | Aegis HFX Resin and OXCE Resin. Honeywell International Inc., Phoenix, AZ, USA |
| Iron Oxidation | Sachets & Film | Fried snacks | Oxygen scavenger | OxyGuard, Clariant Ltd., Mutten, Swaziland |
| Allyl isothiocyanate (AIT) or scavenging molecular O2 (Listeria populations) | Tray/Pads | Ham, ready-to-eat meat product | CO2 emitter and antimicrobial pad | UltraZap R Xtenda Pak pads. Paper Pak Industries, Winnipeg, MB, Canada |
| Titanium Dioxide (Nanoencapsulation) | Powder | Powdered milk-based products | Anticaking | Carnation Instant food. Camation Breakfast |

| | | | | |
|---|---|---|---|---|
| | | | | Essential, Vevey, Switzerland |
| Nanosilver | Bag, Spray | Fruits & Vegetables | Antimicrobial actions | Biomaster. Addmaster Limited, Monrovia, Ca, USA |
| Nanoclay Al203 – 2SiO2 – 2H20 | Film | Dried Fruits, cheeses, coffee | Gas barrier | N-coat. Multifilm Packaging Corporation, Elgin, IL, USA |
| Chancing color based on aromatic compounds (sensor) | Stickers | Fruits | Freshness indicators | RipSense. Ripsense Limited, Tauranga, New Zealand. |
| Cerium oxide | Film | Retort Products and hot fill of meat and fish products | Oxygen scavenger | OMACImperm, Mitsubishi Gas Chemical INC., Chiyoda-ku Japan |
| Sodium carbonate/sodium glycinate | Sachet/Labels | Strawberries, eggplant | CO2 scavenger | Angeless, Mitsubishi Gas Chemical INC., Chiyoda-ku Japan |

| | | | | |
|---|---|---|---|---|
| TTI based on enzyme, Lipase, and pH indicating dye | Stickers | Seafood, Oysters | Freshness (based on color) | TimeStrip, TimeStrip UK Ltd., Cambridge, UK |

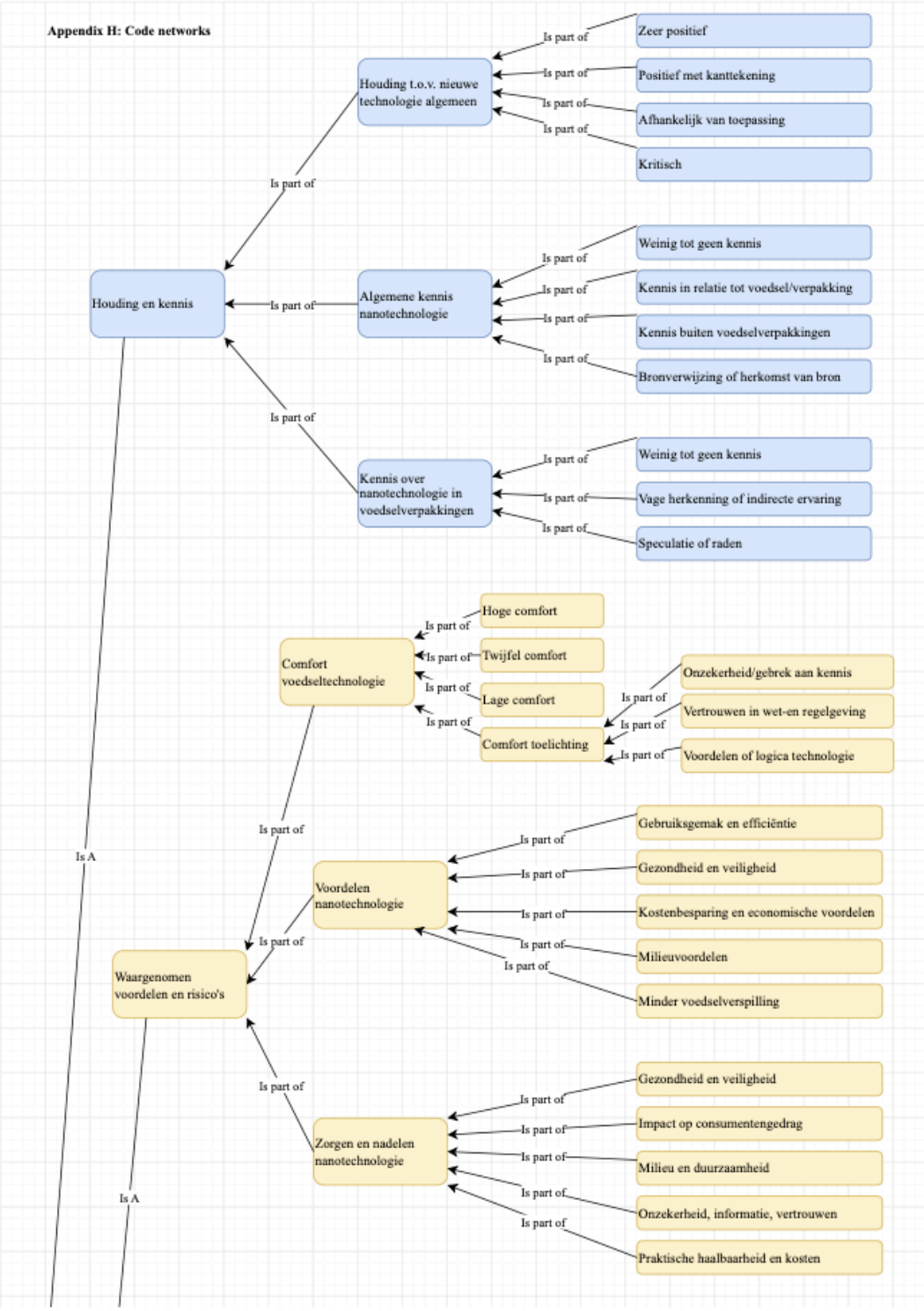
**Table 2**

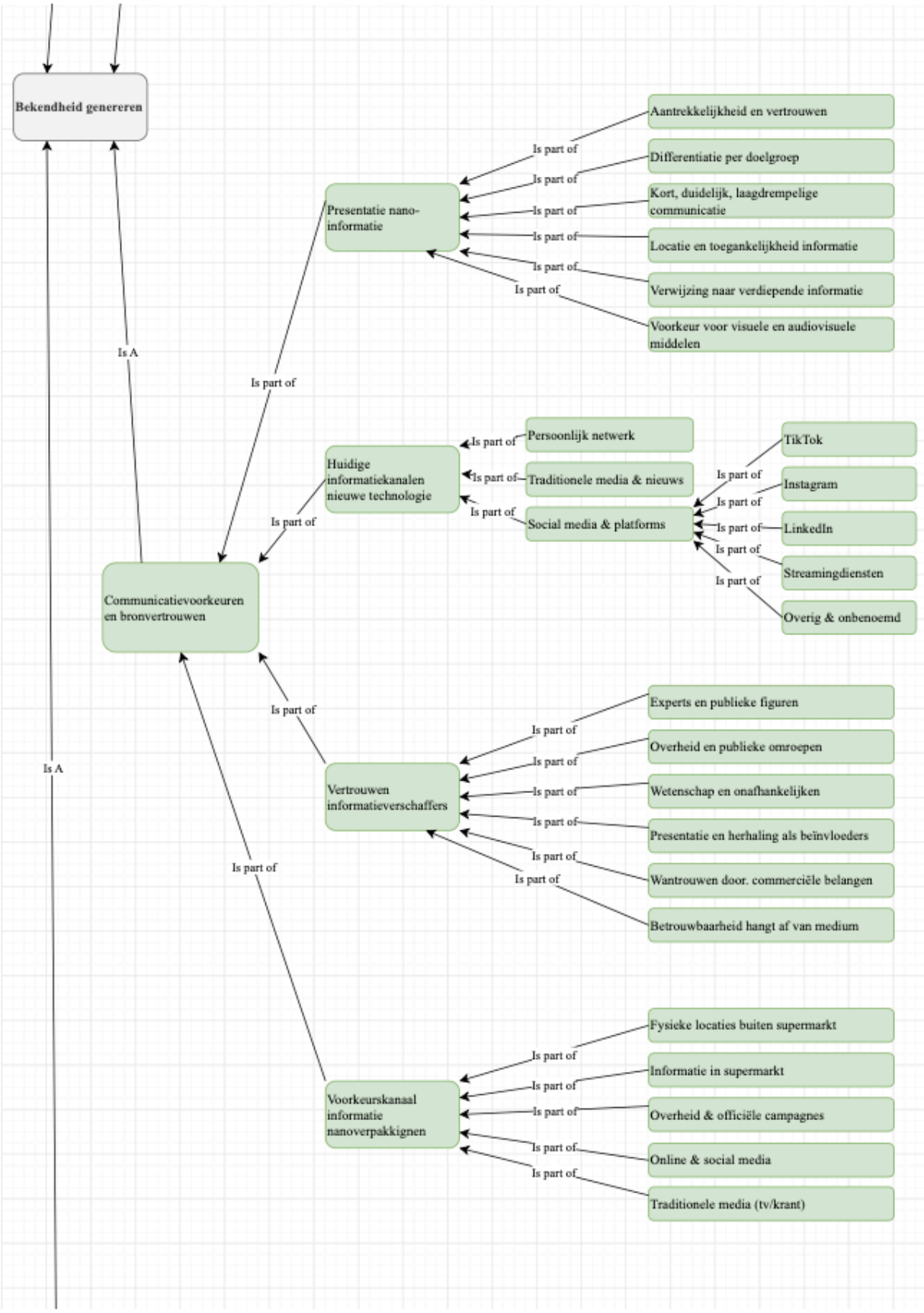
*Commercially available nano-based packaging material*

| S. No. | Brand | Company | Material Type | Product type | Application | Form |
|---|---|---|---|---|---|---|
| 1 | Aegis HFX Resin and OXCE Resin | Honeywell International Inc., USA | nylon 6-nanoclay composite | beer and flavored alcoholic beverage bottles, PET | Oxygen scavenging | Barrier nylon resins |
| 2 | OMAC® Imperm® | Mitsubishi Gas Chemical Inc., Japan | cerium oxide | Retort Product and hot fill of meat and fish products | Oxygen scavenger | Film |
| 3 | OxyGuard® | Clariant Ltd., Swaziland | Iron Oxidation | Fried snacks | Oxygen scavenger | Sachets & Film |
| 4 | ATCOR DE 10S/100 OS/200 OS | Emco Packaging Systems, UK | | Cooked meat | Oxygen Scavenger | Labels |
| 5 | Cryovac® OS Systems | Cryovac Div., Sealed Air Corporation, USA | Polymer Oxidation | Cooked food | Oxygen Scavenger | Tray, Films |
| 6 | Ageless®E | Mitsubishi Gas Chemical Inc., Japan | sodium carbonate/sodium glycinate | Strawberries, eggplant | $CO_2$ scavenger | Sachets/ Labels |
| 7 | Ageless® Ga | Mitsubishi Gas Chemical Inc., Japan | Ferrous carbonate/a mixture of sodium bicarbonate and ascorbic acid. | Meat | $CO_2$ emitters | Sachets |
| 8 | UltraZap R Xtenda Pak pads | Paper Pak Industries, Canada | allyl isothiocyanate (AIT) or scavenging molecular $O_2$ (Listeria populations) | Ham, ready-to-eat meat product | $CO_2$ emitter and antimicrobial pad | Tray/Pads |
| 9 | Microspheres | Bernard Technologies, Inc., USA | chlorine dioxide | Meat, poultry, fish, dairy, confectioneries, and baked goods. | Microbial Contamination | |
| 10 | RipeSense™ Sensor | Ripesense limited, New Zealand | Changing color based on aromatic compounds | Fruits | Freshness Indicators | Stickers |
| 11 | TimeStrip® | TimeStrip UK Ltd, UK | TTI based on enzyme, Lipase, and pH indicating dye | Seafood, Oysters | Freshness(Based on color) | Stickers |
| 12 | N-coat | Multifilm Packing Corporation, USA | Nanoclay $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | Dried Fruits, cheeses, Coffee | Gas Barrier | Film |
| 13 | Biomaster | Addmaster Limited, USA | Nanosilver | Fruits & Vegetables | Antimicrobial packaging | Bag, Spray |
| 14 | Ethysorb ® | Stay Fresh Ltd | PE-Nanoclay composite | Fruits & vegetables | Ethylene Scavengers | Bags |
| 15 | Tip Top bread | George Weston Foods, Enfield, Australia | Nanosized self-assembled liquid structure | Bread | Nano capsule with tuna fish oil | |
| 16 | Carnation Instant food | Carnation Breakfast Essential, Switzerland | Titanium Dioxide (Nanoencapsulation) | Powdered milk-based products | Anticaking | Powder |

*Note.* Reprinted from Table 3 in "Nanotechnology interventions in food packaging and its impact on environment sustainability," by P. Mishra, R. Kumar, & S. Pandey, 2022, Trends in Packaging of Food, Beverages and Other Fast-Moving Consumer Goods (FMCG), 1, p. 6 (https://doi.org/10.1016/j.tfp.2022.01.002). Copyright 2022 by Elsevier.

## Appendix H: Code networks




Bekendheid genereren
Is A
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Communicatievoorkeuren en bronvertrouwen
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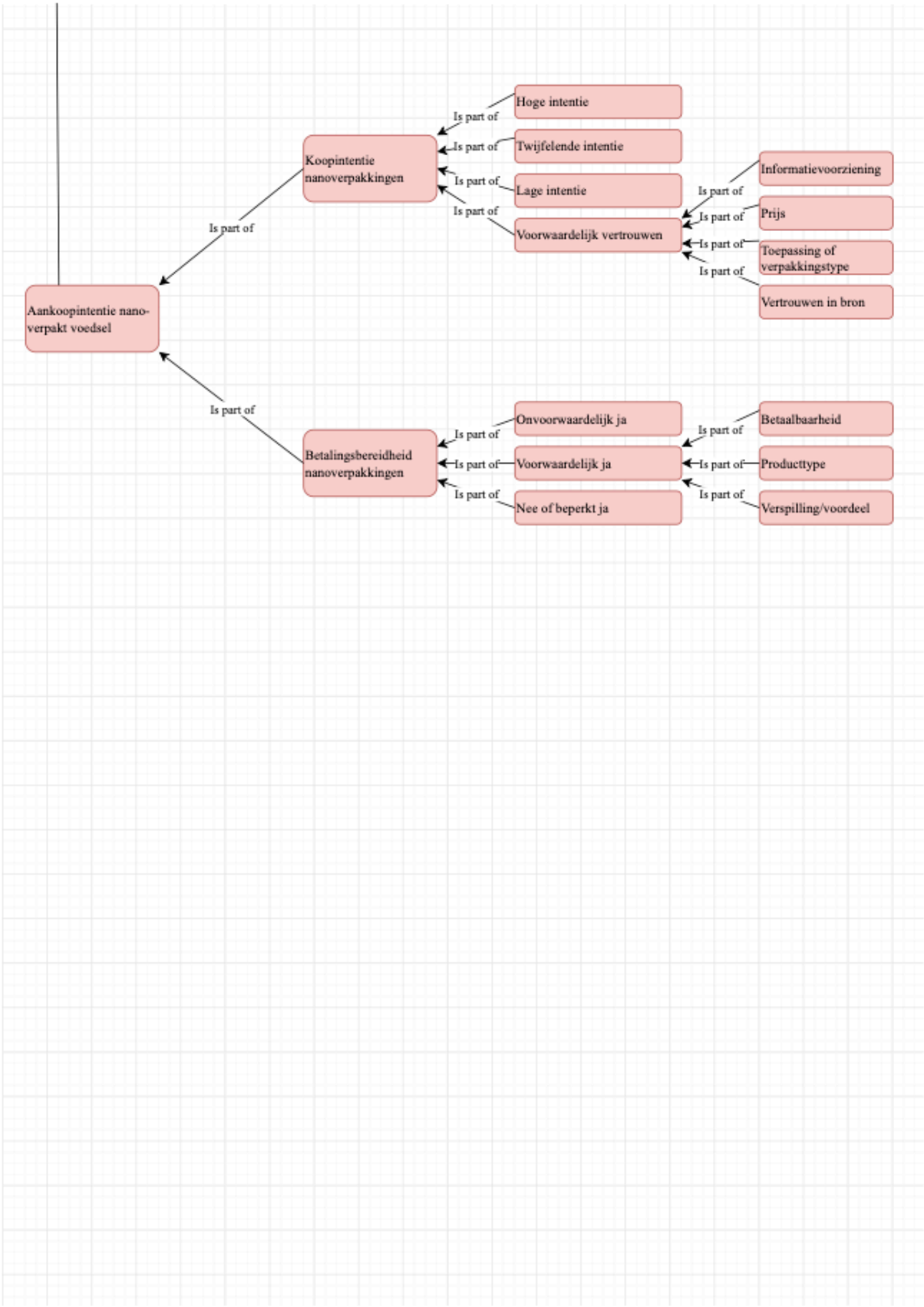
Is part of
Is part of
Presentatie nano-informatie
Is part of
Aantrekkelijkheid en vertrouwen
Is part of
Differentiatie per doelgroep
Is part of
Kort, duidelijk, laagdrempelige communicatie
Is part of
Locatie en toegankelijkheid informatie
Is part of
Verwijzing naar verdiepende informatie
Is part of
Voorkeur voor visuele en audiovisuele middelen
Huidige informatiekanalen nieuwe technologie
Is part of
Persoonlijk netwerk
Is part of
Traditionele media & nieuws
Is part of
Social media & platforms
Is part of
TikTok
Is part of
Instagram
Is part of
LinkedIn
Is part of
Streamingdiensten
Is part of
Overig & onbenoemd
Vertrouwen informatieverschaffers
Is part of
Experts en publieke figuren
Is part of
Overheid en publieke omroepen
Is part of
Wetenschap en onafhankelijken
Is part of
Presentatie en herhaling als beïnvloeders
Is part of
Wantrouwen door. commerciële belangen
Is part of
Betrouwbaarheid hangt af van medium
Voorkeurskanaal informatie nanoverpakkignen
Is part of
Fysieke locaties buiten supermarkt
Is part of
Informatie in supermarkt
Is part of
Overheid & officiële campagnes
Is part of
Online & social media
Is part of
Traditionele media (tv/krant)


Aankoopintentie nano-verpakt voedsel
Is part of
Koopintentie nanoverpakkingen
Is part of
Hoge intentie
Is part of
Twijfelende intentie
Is part of
Lage intentie
Is part of
Voorwaardelijk vertrouwen
Is part of
Informatievoorziening
Is part of
Prijs
Is part of
Toepassing of verpakkingstype
Is part of
Vertrouwen in bron
Is part of
Betalingsbereidheid nanoverpakkingen
Is part of
Onvoorwaardelijk ja
Is part of
Voorwaardelijk ja
Is part of
Nee of beperkt ja
Is part of
Betaalbaarheid
Is part of
Producttype
Is part of
Verspilling/voordeel

**Appendix I: Results**

**Table 3.**

*Overview of attitude and knowledge*

| Main code | Subcode | Description | Example quotes |
|---|---|---|---|
| Attitudes toward new technologies | Very positive | This subcode is used for people who think new technologies are totally fine without critical comments. They indicated an 8 or higher on the scale of 1-10. | *"Yes, I mean, if you think well, eight is of course generally very positive. When I think about the developments in the medical world and what they can do more and more. And of course I think that's all* |
| | Positive with comment | Positive basic attitude toward technology, but with general doubt, skepticism or concern about unknown effects, ethics, long term effects. | *fantastic. And AI, I think that's fantastic on a lot of levels as well. But of course you also notice that more and more with fake news and things that you think, okay, there could be a* |
| | Depending on application | Attitude depends on the specific domain/application of technology. | *group that is going to really abuse that and you have no* |

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|---|---|---|---|
| | Critical | This subcode is used for people whose focus is risk or ethical concerns. The tone is often cautious, even if one does not completely reject technology. | *control over it, and sometimes I find that a bit scary."* – Participant 5, Focus group 3, not eco-conscious consumer. |
| General knowledge of nanotechnology | Little or no knowledge | When people indicate they know nothing or barely know anything. | *"I know t is used in chips making chips, computers and so on. Yes, but the food packaging I haven't heard of before. That's new to me. Uhm yes, other than that I don't know much."* – Participant 2, Focus group 1, not eco-conscious consumer. |
| | Knowledge in relation to food | Knowledge that people have in relation to food or packaging. | |
| | Knowledge beyond food packaging | Knowledge beyond food packaging (e.g. drugs, chips, paint.) | |
| | Source reference or source of origin | Where does the knowledge one has come from. | |

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| Knowledge of nanotechnology in food packaging | Little or no knowledge | For statements like “no,” “no idea,” “nothing,” or “I don't know much about it.” | *"Yes, I do know that you can influence all sorts of things with that. For example, the antibacterial effect of, say, a product or something. Uh, so that bacteria are less likely to develop. So yeah, uh yeah, yeah, that kind of.”*– Participant 5, Focus group 3, not eco-conscious consumer. |
| | Vague recognition or indirect experience | For participants who did notice something or make associations with other contexts (e.g. plastic, coating, sustainability) but are not sure if it is accurate or complete. | |
| | Speculation or guessing | For statements in which participants guess or fantasize what it might be. Often using words such as “maybe,” “could,” “I think...” | |

**Table 4.**

*Overview perceived benefits and risks and being comfortable with nanotechnology*

| Main code | Subcode | Sub-sub-code | Description | Example quotes |
|---|---|---|---|---|
| Concerns and disadvantages of nanotechnology | Health and safety | | Reasons such as is it safe enough, what impact does this packaging method have on my health. | *"Yeah well what earlier had actually also mentioned of if and how sustainable is such packaging and is t it reusable? Or uhm, if it has such a chip in it, can you recycle it? How much more work goes into taking that apart and sorting it?"*– Participant 7, Focus group 2, not eco-conscious consumer. |
| | Impact on consumer behavior | | Consumers wonder what impact it will have on their (shopping)behavior. | |
| | Environment and sustainability | | Are these packages environmentally friendly and sustainable. | |
| | Uncertainty, information, trust | | Broader concerns such as lack of transparency | |

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| | | or lack of clear explanations. | |
| | Practical feasibility and costs | Practical feasibility' is more often at the forefront of conversations about implementation and does these packages become more expensive? | |
| Advantages of nanotechnology in food packaging | Convenience and efficiency | References to statements by participants that focus on practical benefits, simplicity or time savings when using nanotechnology in food packaging. | *"Well, eventually you do if a little less, because I had too. So less waste so less environmental burden and less subsidy needed eh. Because if you see in uh especially in Europe uh what there uh what we what the Dutch farmer get from subsidy, and then I'm* |
| | Health and safety | References to statements in which | |

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| | participants express benefits about the impact of nanotechnology on their physical health or food safety. This is mainly about risk perception, and sense of confidence toward new food technologies. | *not even talking about the French farmer. Well that is terrible, but in fact that costs an awful lot of money. Yeah right? Yes, and that's going to be too. And we have a butter mountain and milk lakes and so on."*– Participant 3, Focus group 4, eco-conscious consumer. |
| Cost reduction and economic benefits | References to statements by participants indicating that nanotechnology in food packaging can lead to financial benefits, both at the individual and societal levels. | |
| Environmental benefits | References to statements in which | |

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| | | participants indicate that nanotechnology in food packaging can have a positive impact on the environment. These include benefits that contribute to sustainability, reduction of environmental damage or more efficient use of resources. | |
| | Reduced food waste | References to statements made by participants indicating that nanotechnology in food packaging can help reduce food waste. | |
| Comfort nanotechnology | High comfort | References to statements where participants indicated | *"And uhm and uhm yes I feel comfortable with it because there are* |

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| | | high comfort with food technology, rated 8 or higher. | *benefits especially on a personal level so yes I like the fact that my food will soon have a longer shelf life. That I won't go wrong with something that's past its date, but that I can just trust that oh it's still good so we can still use it or I can leave it for another two days. So uhm yes say that. The benefits are immediate too."*– Participant 2, Focus group 4, eco-conscious consumer. |
| Doubt comfort | | References to statements where participants indicated they had doubts about being comfortable with food technology, rated between a 4 and 7. | |
| Low comfort | | References to statements where participants indicated low comfort with food technology, rated between a 1and 3. | |
| Comfort explanation | Uncertainty/lack of knowledge | With this code, people report being insecure | |

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| | because they still lack knowledge of the technology. |
| Trust in laws and regulations | With this code, people say they need more confidence in laws and regulations about this technology. |
| Benefits or logic technology | In this code, people indicate they want to experience or understand the benefits and logic behind the technology first. |

**Table 5.**

*Overview communication preferences and source trust*

| Main code | Subcode | Sub-sub-code | Description | Example quotes |
|---|---|---|---|---|
| Present information channels new technologies | Personal network | | These references are directed work, education, friends, all forms of interpersonal contact. | *"Especially social media and the news indeed. Uh the the the the apps of t news and uh. But also, just uh yes, in your environment, your own network. Yes, yes, what is the name of the case? Uh, regular information and indeed news. Uh, on television or something? News programs yes. Or talk shows? Uh, if there happens to be a guest? Uh yes, those."*– Participant 5, Focus |
| | Traditional media and news | | These references are focused on television, newspaper, radio, podcast (podcast can also be under social media). | |
| | Social media and platforms | TikTok | These references are aimed at gathering information through TikTok. | |

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|---|---|---|
| | | group 3, not eco-conscious consumer. |
| Instagram | These references are aimed at gathering information through Instagram. | |
| LinkedIn | These references are aimed at gathering information through LinkedIn. | |
| Streaming services | These references are aimed at gathering information through streaming services. | |
| Other and unidentified | These references are aimed at gathering information through YouTube, blogs, catalogs. | |

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| Trust in information providers | Experts and public figures | References to statements made by participants indicating their confidence in information coming from experts, such as scientists, professors or public figures with substantive expertise. | *"Depends what sources they use and what persons say things. Yes, if I see in texts, uh yes of course you can have doubts. But if they say for example professor or a scientist has done this and this and based on that and that and that research. Then I trust t more than if t is just an interview with someone."*– Participant 6, Focus group 2, not eco-conscious consumer. |
| | Government and public broadcast | Includes statements by participants indicating that they trust information coming from government agencies or public broadcasts. | |
| | Science and independents | Includes all statements in which participants express confidence or preference for | |

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| | information coming from scientists, researchers, universities or independent organizations - those with no commercial interest. |
| Presentation and repetition as influencers | Refers to how information about nanotechnology (or other new technologies) is presented and repeated - and how this affects consumer confidence, understanding and acceptance. |
| Distrust due to commercial interests | This subcode includes all statements and observations in which distrust arises because |

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| | | participants believe the information or technology is driven by commercial motives rather than objective or societal interests. | |
| | Reliability depends on medium | his subcode includes all comments in which participants indicated that their confidence in information depends on the channel or platform on which that information appears. | |
| Preferred channels information nano packaging | Physical locations outside supermarket | This subcode includes all statements in which participants indicated they would like to receive information about nanotechnology | *"Yes yes or that you can read that information at UH in different places from me part do it for the elderly in the library or so. Uhm yes, that they get* |

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| | in food packaging in places outside the supermarket. These are alternative, physical locations where information can be easily accessed without necessarily being linked to the supermarket purchase moment. | *some information or that it comes after the news or things like that and that you see the short explanation in the supermarket. Yes, because then you want to choose quickly anyway, you don't want to stand 1.00h say yes and uh some more extensive explanations with for example the news or I don't know what current affairs programs then but are."*– Participant 4, Focus group 1, not eco-conscious consumer. |
| Information in supermarkets | This subcode includes all comments from participants indicating they would like to receive information about nanotechnology in food packaging in or around the supermarket. | |
| Government and official campaigns | This subcode includes all statements in which | |

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| | participants indicated confidence in information coming from the government or government-initiated public campaigns. It refers to communication from official agencies, such as ministries, food authorities or public information campaigns about new technologies such as nanotechnology in food packaging. |
| Online and social media | This subcode includes all statements in which participants refer to online platforms or social media as a source of information about nanotechnology or food |

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|---|---|
| | packaging. It includes both spontaneous encounter of information and active search through digital channels. |
| Traditional media (television/newspaper) | This subcode refers to all statements in which participants mention traditional media channels as a source of information about this technology. These are offline and established media forms that have been around for a long time and are often perceived as more reliable than social media. |

| | | | |
|---|---|---|---|
| Preferred channels information nano packaging | Physical locations outside supermarket | This subcode includes all statements in which participants indicated they would like to receive information about nanotechnology in food packaging in places outside the supermarket. These are alternative, physical locations where information can be easily accessed without necessarily being linked to the supermarket purchase moment. | *"And I even think that like the pictures you showed at the beginning. Where you say that maybe it's a little childlike, but I think that for everyone, whether you're young or old, that's what appeals most. We are quite visual. If we must read long texts. We're also lazy, so we tend to give up, especially if we must read a bit of technical information."*– Participant 5, Focus group 3, not eco-conscious consumer. |
| Presentation nano information | Attractiveness and trust | This subcode includes all participants' statements focusing on the degree of attractiveness and sense | |

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|---|---|
| | of confidence in the way information is presented. |
| Differentiation by target audience | This subcode includes all statements in which participants indicate that communication about nanotechnology (or food packaging in general) should be tailored to different audiences. It recognizes that not every consumer thinks, learns or wants to be informed in the same way. |
| Short, clear, approachable communication | This subcode includes all statements in which participants indicated that they would like to |

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| | receive information about nanotechnology in food packaging in a concise, understandable and accessible manner. |
| Location, and accessibility of information | This subcode includes statements in which participants indicate where and how easily they would like to receive information about nanotechnology in food packaging. Thus, this is not just about the content, but more importantly the place and ease of finding or understanding that information. |

| | |
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| Reference to in-depth information | This subcode includes statements from participants indicating a need for more in-depth information, provided it is offered without obligation and accessible. This is not basic explanations on the package itself, but an option to read, watch or explore further on their own when desired. |
| Preference for visual and audiovisual resources | This subcode refers to statements in which participants indicated that they prefer information about nanotechnology in food packaging to be |

presented visually or
audio visually.

**Table 6.**

*Overview purchase intention nano-packaged food*

| Main code | Subcode | Sub-sub-code | Description | Example quotes |
|---|---|---|---|---|
| Purchase intention of nano packaging | High intention | | This subcode refers to statements in which participants indicated that they have a high purchase intention, where a rating between 8 and 10 was given. | *"Yeah, I think so. I 'm going to guess, because I'm just in between. So, then I say a five right now. Yeah, uhm yeah, I just think it's a really good idea. But indeed, what you also just say* |
| | Doubting intention | | This subcode refers to statements in which participants indicated that they had a doubting purchase intention, where a rating between 4 and 7 was given. | *there's just not enough information yet. Uhm yes, but I think so if it just works really well. And indeed. So the risks are very minimal that then of course it works really well. And then I* |
| | Low intention | | This subcode refers to statements in which | *would buy it anyway. I am indeed the type of* |

| | | | |
|---|---|---|---|
| | | participants indicated low purchase intention, where a rating between 1 and 3 was given. | *person who will buy products for the longer term. So yes, the opposite of what you just said, for example, so then it really is a nice opportunity, but for the moment I'm in between, because I really need more information about it."*– Participant 5, Focus group 1, not eco-conscious consumer. |
| Conditional trust | Information provision | This sub-sub-code refers to statements in which participants indicated that the purchase intention depends on additional information or explanation | |
| | Price | This sub-sub-code refers to statements in which participants indicated that purchase intent is dependent on price. | |
| | Application or packaging type | This sub-sub-code refers to statements in which participants indicated | |

| | | | | |
|---|---|---|---|---|
| | | | that the purchase intention depends on the application or packaging type. | |
| | | Confidence in source | This sub-sub-code refers to statements in which participants indicate that purchase intent depends on the confidence they have in the source. | |
| Willingness to pay for nano packaging | Unconditionally yes | | This subcode refers to statements in which participants indicate that they would unconditionally be willing to pay more for food packaged with nanotechnology. | *"But I also do think it depends a lot on your situation. I mean uh I go every day, I do my shopping every day and I uh well, I walk into the Albert Heijn within a minute, so that's a very different situation for* |

| | | | |
|---|---|---|---|
| Conditionally yes | Affordability | This subcode refers to statements in which participants indicate that they are willing to pay more, but it must remain affordable. | *me. Yes, but I also lived out of town for a while with a couple of young kids. Well then, I was getting food for the whole week and then I definitely would have paid more for that* |
| | Product type | This subcode refers to statements in which participants say they are willing to pay more, but it is product-dependent for them. | *because I also threw away quite a lot more during that period. Because then you start planning or four days in advance. I'm going to* |
| | Waste/benefit | This subcode refers to statements in which participants indicate that they are willing to pay more, but they must truly experience reduced food waste and benefits. | *do this, do that and then something comes up in between and then you end up having to throw it away. If I could then use nanotechnology and for an additional cost to keep food good longer, I* |

| | | |
|---|---|---|
| No or limited yes | This subcode refers to statements in which participants indicate that they do not want to pay more, relative rejection. | *would have spent that money on it, guaranteed."*– Participant 4, Focus group 3, not eco-conscious consumer. |

**Appendix J: Three methods of nano packaging**

**Improved Packaging (IP)** focuses on improving the physical properties of packaging materials, such as strength, heat resistance, and moisture and gas barrier capabilities (Kuswandi & Moradi, 2019). For example, incorporating bentonite nano clay into polyethylene terephthalate (PET) strengthens the material without increasing plastic use, as seen in yogurt packaging (Statnano, 2018). IP also enhances renewable biopolymers like polylactic acid, chitosan, cellulose, and starch. Adding nanocellulose crystals to polylactic acid improves oxygen and water barrier properties, suitable for products like packaged salads (Fortunati et al., 2012). These adaptations optimize both traditional and sustainable packaging methods.

The second use, **Active Packaging (AP)**, focusses on food preservation by either absorbing particles linked to spoiling, such as ethylene and oxygen, or releasing antimicrobial agents. Colloidal silver lunch boxes in the UK are an example of how silver nanoparticles embedded in polymers have antibacterial and antifungal qualities (Statnano, 2016). Fruit ripening is slowed by the absorption of ethylene gas by nanomaterials like zeolite. Products like Evert Fresh Co.'s Green Bags in the USA use this to extend the shelf life of fruits like bananas (Sadeghi et al., 2019). These developments help reduce waste in addition to preserving food.

The third technique, **Smart Packaging (SP)**, allows the monitoring of food quality using nanosensors that respond to changes in the environment by acting as labels, colors, or coatings. To indicate changes in the state of the food, these sensors change visual characteristics like color. For instance, the French company Cryolog's Topcryo® labels, which turn from green to maroon when the cold chain is disrupted, signal that the food has been spoiled (Enescu et al., 2019). Fluoro-functionalized graphene, which changes color when it detects amines or ammonia

during fish spoiling is another use for this material (Rouhani, 2019). By providing customers with real-time feedback, SP creates increased transparency and trust.