UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento Territorio e Sistemi Agro-forestali

Department of Land, Environment Agriculture and Forestry

Corso di laurea magistrale/Second Cycle Degree (MSc)

In Food and Health

Exploring milk and dairy companies' attitudes toward the adoption of microplastics detection technologies

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Sommario

Abstract

Microplastics (MP) contamination in food, particularly milk, presents significant concerns for food safety and human health. With increasing global plastic production, MP pollution has become widespread. The increasing concern over microplastic contamination in the food industry necessitates effective detection methods to ensure food safety and quality. But first, the adoption of these technologies by companies should be investigated because if companies do not accept the technologies to apply in order to detect the MPs in their products, no further improvement could be expected. This master's thesis investigates the adoption of microplastics detection in milk within Small and Medium Enterprises (SMEs) in the Netherlands. Grounded in the Technology Readiness and Acceptance Model (TRAM), the study explores the perceived usefulness and readiness for technology adoption among dairy industry professionals through expert interviews. While some recognized the potential benefits for improving product quality and market competitiveness and considered these technologies useful and were ready to adopt them, they also expressed concerns about technology reliability and cost. Moreover, consumers' attitudes toward microplastic-free products, their willingness to pay for microplastic-free products, and factors that can influence the willingness and ways to improve awareness among consumers were explored.

CHAPTER 1

INTRODUCTION

1.1 Background and literature review

1.1.1 What is Microplastic

Plastic particles that are less than 5 mm, referred to as microplastics, have become a major environmental problem (123). Microplastics have become a significant issue in the food industry because of their potential health risks and their effects on food quality. The detection of microplastics is very important to ensure compliance with food safety and quality regulations. Over the past seven decades, the global production of plastic has increased, releasing approximately 4900 million tons into the environment between 1950 and 2015 (1). Microplastics, defined as plastics less than 5 mm in size, fall into two categories: primary and secondary (2). Primary microplastics often originate from individual actions directly, and secondary microplastics are predominantly formed through the breakdown of larger particles as a result of biodegradation or chemical degradation processes (3). Microplastics come in a range of materials, sizes, and shapes. Acrylic, polyethylene, polypropylene, polyamide, and polyester fragments are the most frequently identified plastic materials found in nature (4).

Over the past 10 years, plastic pollution has garnered significant attention and become a noticeable subject of discussion and concern due to its widespread occurrence in ecosystems. Microplastics, in particular, have contributed to large environmental contamination in both marine and terrestrial environments (45). Human exposure to microplastics primarily occurs via the consumption of contaminated food and beverages ((46),(47)).

1.1.2 Microplastics negative effects

Microplastics can emit harmful and toxic monomers, like bisphenol A, and serve as a conduit for the transmission of environmental pollutants, including persistent organic pollutants, polycyclic aromatic hydrocarbons, and heavy metals (5). Smaller microplastics can pose an elevated risk due to their increased likelihood of crossing the intestinal barrier (6). Microplastics exert adverse effects on living organisms, manifesting as disruptions in energy metabolism, oxidative imbalance, and damage to DNA and immunological systems (7). The morphology and surface characteristics

of microplastics also impact their toxicity attributes (8). Initially, research efforts concentrated on aquatic systems (9), embracing water (10), biota, ((11),(12),(13)) and sediment (14). However, recent investigations have expanded to include agricultural and food systems. Approximately 39,000 to 52,000 microplastic particles are estimated to be ingested per year by Americans through food consumption (15). The biopersistence of MPs might lead to many biological reactions like inflammation, genotoxicity, oxidative stress, apoptosis, and necrosis (48). The extensive surface area of microplastics can induce oxidative stress, cytotoxicity, and translocation to various tissues. However, their persistent structure hinders their elimination from the organism, fostering chronic inflammation and elevating the risk of cancer ((49),(50)).

1.1.3 Microplastics in milk

Microplastics have been identified in different foods like seafood, water, mineral water, soft drinks, cold tea, energy drinks, honey, salt, sugar, and milk ((51),(52), (53),(54),(55),(56),(57),(58)). This study focuses its investigation on commercial milk, a rich source of calcium, protein, minerals, vitamins, and other essential nutrients crucial for human nutrition. Previous reports have shown the presence of microplastics in both raw and processed milk. ((59),(60)). Microplastic contamination has been identified to occur in various ways, like inhalation and ingestion by cows, that ultimately cause its presence in milk. Additionally, microplastics can originate from each step of the production process and packaging. ((61),(62),(63)). The concentration of microplastics detected in milk samples varied from 204 to 1004 microplastics per 100 mL of sample. Great numbers of microplastics had a surface area of ≤ 50 μm2, forming between 69% and 89% of the total microplastics identified in the milk samples (18).

1.1.4 Why milk?

Many researchers have underscored the importance of monitoring and doing risk assessments on microplastic levels in food products ((66),(67), (68),(69),(70),(71)). From birth to all of the life stages, drinking milk is an important part of human nutrition ((64),(65)). Due to the potential hazards that microplastics pose to human health, particularly with food consumption, ensuring the safety of milk is serious.

1.1.5 Detection methods

Manufacturers should first use special technology to detect the MPs. While there isn't a dedicated technology for detecting microplastics yet, Fourier transform infrared (FT-IR) and Raman technology, already employed in various industries for different purposes, can be utilized for the detection of MPs in milk. Raman spectroscopy, in particular, has emerged as a strong analytical technique for this purpose ((19),(20),(21),(22)). Microplastics, comprising diverse polymers, show unique Raman spectra that facilitate the determination of their chemical composition. This uniqueness allows for the identification and differentiation of various types of microplastics based on their individual Raman spectra (23). FT-IR, including ATR-FT-IR and μ-FT-IR, can be used for the detection of MPs (72). This method offers the advantage of simultaneously detecting abundance, identifying polymer types, and inferring the chemical characteristics and structures of microplastics (MPs) in samples. Fourier Transform Infrared (FT-IR) technology can identify MPs smaller than 1000 μm; this ability is beyond visual identification. With matching rates of the spectrum exceeding 60%, Raman spectroscopy has been used to identify MPs in beverages, condiments, honey, and seafood, capable of analyzing MPs as small as < 1 μm in size ((73),(74)). Microplastics are commonly identified and characterized using Fourier Transform Infrared (FTIR) spectroscopy. This method involves measuring a sample's absorption or transmission of infrared radiation, offering insights into the sample's chemical composition and the variety of microplastics present (24). While adopting special equipment can be beneficial, it may not always be possible because of factors such as cost and the need for expertise (75).

1.1.6 Technology Adoption

Technology adoption constitutes a well-established realm of research. Carr (88) has delineated it as the process of selecting a technology for utilization by individuals or organizations. As technological innovations proliferate across various domains at a rapid pace, concerns regarding technology adoption have garnered heightened attention. Organizations and governments allocate substantial investments toward introducing novel technologies capable of catalyzing a paradigmatic shift in user lifestyles. Nonetheless, the efficacy of these investments depends on the adoption of innovations by their intended users. (25). What is technology? Technology refers to novel and better methods of achieving economic goals that contribute to economic expansion ((26),(27)). Adoption is defined as the determination to fully utilize an innovation, often

synonymous with new technology, regarded as the most advantageous course of action, typically involving a progression through various stages of acceptance (28). Individual decisions to adopt are shaped by the attributes of potential adopters, along with their perceptions of the innovation's characteristics, adoption behaviors, and the learning and communication processes inherent in the different stages of the innovation decision-making process ((29),(30)). The theories and models that have evolved to explain the adoption of technology are summarized below.

1.1.7 Technology adoption theories

Three primary theories have been employed in examining technology adoption: (i) the Technology Adoption Model (TAM), which centres on users' acceptance of technology adoption driven by their perceptions of its usefulness and ease of use, as formulated by Davis (31); (ii) the Diffusion of Innovation theory (DOI), which outlines how innovation spreads through communication within a social system, as posited by Rogers (32); (iii) the Technology-Organization-Environment (TOE) framework, which encompasses the adoption decision of technological innovation considering technological, organizational, and external environmental contexts, as introduced by Tornatzky and Fleischer (33).

While numerous models for technology acceptance have emerged from various researchers, the TAM model retains significance as it continues to be acknowledged by both academic and industrial researchers (35). The TAM model is preferred for its focus on individual technology acceptance capacity, contrasting with the Unified Theory of Acceptance and Use of Technology (UTAUT) model, which is tailored for organizational-level acceptance and usage of technology (36). Hence, this study centres on individual users' perceptions, advocating for the adoption of the TAM model.

TAM is suggested for situations where technology acceptance is in its initial adoption phase ((37),(38)). The TAM, introduced by Davis, stems from the Theory of Reasoned Action (TRA) developed by Fishbein and Ajzen (40). In psychological research, the Theory of Reasoned Action (TRA) suggests that individual behavior is influenced by behavioral intention, which is shaped by attitudes toward the behavior and subjective norms. Essentially, behavior is believed to be a result of both personal attitudes and social influences. Building on this framework, the Technology Acceptance Model posits that users' attitudes toward using technology and their perceived ease of use and usefulness of the technology predict their behavioral intentions and actual usage. Perceived

ease of use (PEOU) refers to the user's perception of how effortless it is to use the technology, while perceived usefulness (PU) reflects the user's belief that the technology will enhance their work performance. TAM suggests that these factors collectively influence the user's attitude toward technology use, which in turn determines their intention to use it (39). However, despite its common usage, TAM has faced extensive criticism for its perceived simplicity, restricted ability to explain and predict outcomes, and perceived lack of novelty and practical utility (34). Moreover, considering individual differences, the author aims to enhance the understanding of consumers' intentions to use MP detection technologies by integrating the concept of technology readiness (TR) (81) with TAM. TR reflects consumers' general attitudes toward technology and their engagement with technology-based products (81). The study seeks to complement the TR construct with the key components of TAM, perceived usefulness, and perceived ease of use. This integration leads to the development of a unified model, the Technology Readiness and Acceptance Model (TRAM), aimed at providing insights into consumer adoption behaviors regarding these new technologies (42).

1.1.8 Technology Readiness and Acceptance Model

The Technology Readiness and Acceptance Model (TRAM) integrates elements of both the Technology Acceptance Model (TAM) and the Technology Readiness (TR) (42). Technology readiness (TR) was determined by Parasuraman ((94),((81),(82),(83)). According to Parasuraman, technology readiness can be defined as "the propensity of people to embrace and use new technologies to achieve goals in home life and work" and reflects a person's overall state of mind influenced by various factors, determining their inclination to adopt and use new technologies (96) and Technology readiness is also a predictor of perceived usefulness (98). This integration sheds light on how individual personality traits can impact how people engage with, perceive, and adopt new technologies. In its pioneering effort to amalgamate these frameworks, technology readiness was leveraged as a predictor within TAM (42).

A recent study (104) established a direct association between the components of technology readiness and the dimensions of TAM, namely perceived usefulness and perceived ease of use. This linkage has led to the development of a more targeted and refined model (43). This concept encompasses four distinct dimensions. The first two components are characterized by positive sentiments: optimism, which entails the belief that technology will yield efficiency, control, benefits, and flexibility, and innovation, which involves being an early adopter of innovative

technology-based services or products (84). Conversely, the remaining two components are associated with negative sentiments: discomfort, which reflects an individual's perception of lacking control and confidence in using the technology, and insecurity, which entails a fear that the technology-based service, product, or process may not function accurately or reliably. These four dimensions of technology readiness are independent of one another and reflect an individual's behavioral disposition and overall attitudes toward technology (95). Positivity and willingness to innovate are believed to correlate with greater perceived usefulness and ease of use of a particular technology. Conversely, feelings of insecurity and discomfort are proposed to hinder these dimensions of TAM (44). TRAM is a combination of TAM with Technology Readiness (TR) (93). Individuals with higher levels of technology readiness are more likely to adopt new technologies at a faster rate and use them more intensively, experiencing higher ease in their usage ((97),(98)).

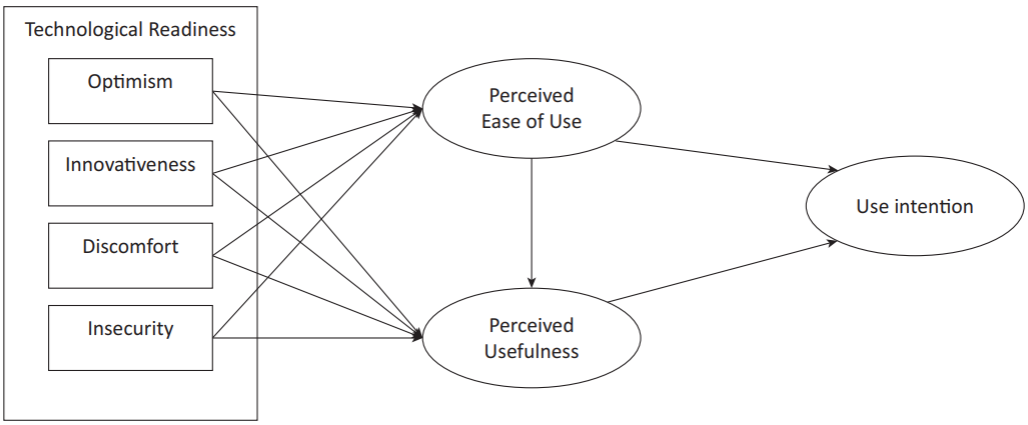


Figure 1. Theoretical model based on TRAM (Lin et al., 2007).

((42),(78))

1.1.9 Focusing on optimism, insecurity, and Perceived usefulness from TRAM

While the Technology Readiness and Acceptance Model (TRAM) includes optimism, innovativeness, discomfort, and insecurity in the technological readiness section, as well as PU and perceived ease of use (PEOU), this study focuses specifically on optimism, insecurity, and perceived usefulness. Some researchers ((105),(106)) have suggested that PU is a more influential predictor of technology adoption compared to PEOU. This implies that even if a technology is easy to use, its adoption is primarily driven by its perceived usefulness to the user (80).

Furthermore, as this research does not focus on one specific MP detection technology, PEOU could not be explored because each technology has its own features. Additionally, a study (109) suggests that TR is best conceptualized as a two-dimensional construct differentiating between motivators and inhibitors. In this thesis, between insecurity and discomfort as inhibitors, insecurity was chosen. Discomfort is a supposed absence of support, anxiety, uneasiness, and nervousness (108), which mostly aligns with PEOU (that it is not going to be explored in this study). Insecurity entails a lack of trust in technology and skepticism regarding its effectiveness (86); it is linked more with PU. Taking into account both the expert's level of knowledge and the novelty of the subject, insecurity was chosen to be explored. For the motivator dimension, an optimistic point of view of technology that suggests new technological advancements was chosen due to the fact that it will increase utility by providing more control, flexibility, and efficiency. Those adopting an optimistic strategy typically achieve expected outcomes more effectively (85) and align more with PU. Moreover, innovativeness is a tendency to be the first to use a novel technology that according to some studies may negatively impact perceived usefulness (43). Overall, while TRAM is a very comprehensive and detailed framework, due to some restrictions like time and considering MP detection technologies as not just one specific technology, using the common TRAM was impossible, so a new model of modified TRAM was used. Figure 2 displays the model we will be exploring.

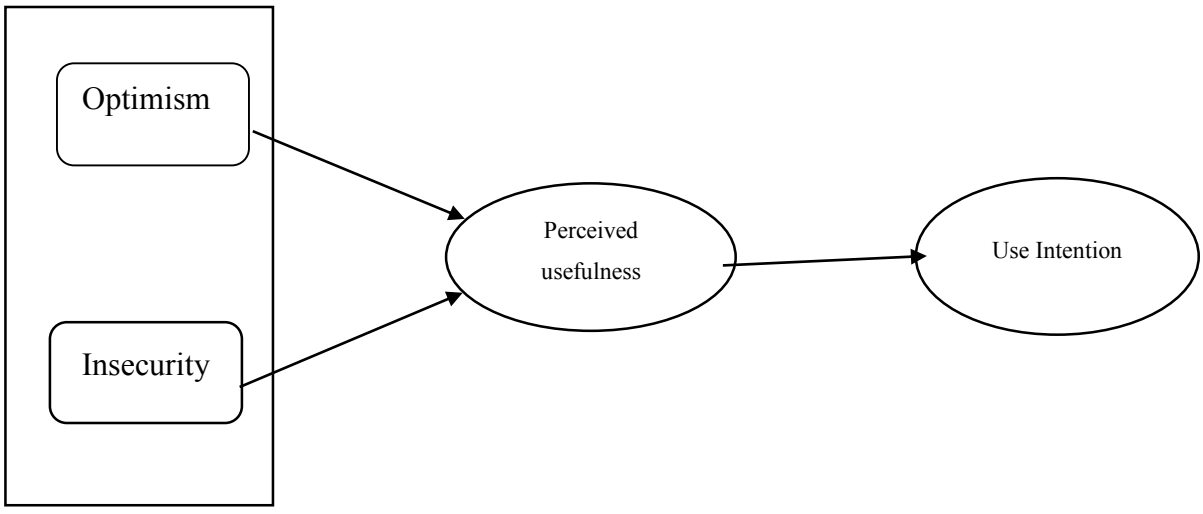


Figure 2. Actual used framework

1.2 Demarcation

1.2.1 Geographical demarcation

One part of this study focuses on SME milk companies in the Netherlands. The second part explores milk consumers in European Union.

1.2.2 Size of the companies

The definition of Small and Medium-sized Enterprises (SMEs) in the European Union is outlined in the EU Recommendation 2003/361/EC. This recommendation provides the criteria for categorizing enterprises based on staff headcount, turnover, and balance sheet totals. The European Union (EU) defines a Small and Medium-sized Enterprise (SME) as a business entity with fewer than 250 employees, a turnover of less than €50 million, or a balance sheet total of less than €43 million ((103),(92)). Small and Medium Enterprises (SMEs) are a cornerstone of Western economies and constitute the most prevalent type of business organization in Europe (76).

1.2.3 Quality definition

The term "quality" originates from the Latin word “qualitatis,” which in turn comes from the word "qualis," meaning "which" and therefore "of which character". The use was introduced by Cicero. This etymology suggests that quality can be interpreted as "how like" or characteristics. (90). However, this also implies that the term ‘quality’ lacks a fixed definition. Consequently, quality often carries different interpretations, even when discussing the same subject. This variance in interpretation is notably evident in discussions surrounding raw milk quality. In the recent decade, the quality parameters used to determine whether milk is suitable for sale by a farmer, have increased from simple sensory evaluations using sight and taste to complex analyses for the presence of chemical residues (116). For instance, milk producers may define quality as the optimal performance of their herd, resulting in high yields, fat, and/or protein content, possibly alongside low cell numbers, which are attributes for which the dairy compensates them. Finally, consumers prioritize safety, taste, affordability, and healthiness as key quality attributes (77). In this research quality, means milk without MPs.

1.3 Problem statement

Fourier transform infrared (FTIR) and Raman spectroscopy are reliable techniques for the detection and identification of microplastics that are able to specify both the type and shape of these particles (79). Despite their efficacy, microplastics detection technologies in dairy manufacturing processes have not been incorporated into quality control measures (91) because microplastics are frequently found in milk samples (115), and there are no specific guidelines within the Codex Alimentarius or Hazard Analysis and Critical Control Points (HACCP) addressing this issue. This pretermission is concerning because of the potential health risks posed by microplastics in dairy products. Presently, standardized methods for quality assurance and quality control (QA/QC) and the collection of samples for microplastic assessment in dairy cannot be found (91). Although the Deutsches Institut für Normung (DIN) in Germany recently published the DIN/TS 10068 Act, which involves methods such as FTIR and Raman spectroscopy for the identification and quantification of microplastics, these standards are primarily national. Conversely, ISO 24187:2023, developed by the International Organization for Standardization, offers methods for detecting and analysing microplastics in environmental samples with potential applicability to food. However, these ISO standards are not mandatory unless adopted and enforced by national regulations. Moreover, the fact that there are fats and proteins in milk, which can bind to microplastics (117), suggests that the methodologies for sampling and analyzing milk and dairy products may differ from those used for soil and water samples. These differences are not adequately addressed in ISO 24187. This gap in regulation and standardization raises critical questions about the ability of companies to assure consumers that their products are free of microplastics, while there are detection technologies on the market. This research aims to explore the attitudes of companies towards the adoption of microplastic detection technologies, considering the perceived usefulness (PU) and technology readiness (TR) within the Technology Readiness and Acceptance Model (TRAM). Additionally, the study will investigate consumers' attitudes towards microplastic-free dairy products, their willingness to pay for mp-free products, examine how increased awareness can influence consumer willingness to pay, and propose strategies to enhance consumer awareness regarding microplastics in dairy products.

1.4 Research aim and research questions

This study aimed to explore the familiarity of companies with microplastics and their negative effects on human health and to investigate what is the business operators' attitudes toward the adoption of microplastics detection technologies in their companies, considering TRAM theory. The research questions of the thesis are the following

RQ1: How do milk firms see MPs detection technologies' usefulness under Technology Readiness and Acceptance Model (TRAM)?

RQ2: How do milk firms see their readiness to deploy MPs detection technology using the Technology Readiness and Acceptance Model (TRAM)?

RQ3: According to PU and TR of companies, what will be their intention to adopt these technologies?

RQ4: What will be the consumers' attitude toward microplastic and microplastic-free product?

RQ5: Are consumer willing to pay more for a MP free product and if yes how much?

RQ6: If awareness about microplastics can affect consumers' attitudes toward microplastic-free dairy products and how we can improve awareness about Microplastics and their negative health effect among consumers?

CHAPTER 2

Methodology

2.1 Research design

The research consisted of three stages of gathering information: a literature review, interviews, and a survey. A systematic literature review was done in order to understand microplastics and their negative effects on health, the available detection technologies to use in companies as a means of improving quality in their products, and understanding technology adoption theories to find out about companies' attitudes toward accepting microplastics detection technologies in their labs and how PU and TR can influence technology adoption, as described in the Introduction section. An empirical study, in the form of expert interviews, was then conducted to investigate companies' readiness and perceived usefulness of microplastic detection technologies. Interviews were conducted with experts employed in various companies. In the third part, a survey is conducted to explore consumer attitudes toward microplastics and microplastic-free products, their willingness to pay more for microplastic-free products, and factors that can influence the willingness and ways of improving awareness among consumers about microplastics.

2.2 Literature review

2.2.1 Performing the systematic literature review

We conducted a thorough review of the existing literature to cultivate a general and extensive understanding of microplastics detection technologies and technology adoption theories. This process encompassed the scrutiny of various scholarly articles, books, and credible online sources pertinent to the research domain. Academic databases such as PubMed, Google Scholar, and Science Direct were utilized for systematic searches using keywords and search terms like TAM, Technology Acceptance and Readiness Model, Microplastic, Microplastic in Milk, Quality, Microplastic and Quality, Microplastic Negative Effects on Health, Microplastics Detection Technologies FT-IR, RAMAN, Technology Adoption Theories, and SME. Criteria for inclusion of literature focused on relevance to the research questions; the most recent publications date from 1986 (the year of the first publications of Fred Davis, who introduced the technology acceptance model) until 2024. Through this process, gaps, trends, and conflicting viewpoints within the

existing body of knowledge were identified and analyzed, serving as a foundational step in shaping the design and direction of the study.

2.3 Snowballing

In addition to conducting a literature review, a snowballing approach was implemented to augment the breadth of the research. This involved identifying pivotal references from the initial literature set and then systematically exploring additional sources cited within those references. Snowballing proves particularly advantageous for expanding systematic literature studies, as new studies inevitably reference previously relevant papers or systematic studies in the field. One key benefit of this approach is that it begins with pertinent papers, leveraging them to guide further investigation. Reference lists are easily scrutinized, and when contextualized with the reference's origin and significance, relevant papers can be readily identified in most cases (89).

2.4 Empirical studies design

In association with the literature review and snowballing technique, empirical studies were also conducted as a methodological approach to fortify the research attempt. We asked experts in the dairy-based product production sector to participate in an interview and respond to a questionnaire, aiming to gather sector-specific data on PU and TR, which we then compared to the theoretical information in the literature. Experts in dairy companies with background in managerial level employed by dairy SMEs within the Netherlands were selectively approached for interviews. Contact was made through various channels, such as email, telephone, and the companies' websites. Appendix 2 contains the list of companies we contacted. The research report does not share the information of the experts contacted separately due to confidentiality reasons. Appendix 3 presents the emails sent to the experts and the companies. Additionally, a survey with multiple choice questions was conducted to investigate consumers' attitudes toward microplastics and microplastic-free dairy products, and explore whether awareness about microplastics and their negative health effects can affect people's attitude, and willingness to pay for microplastic-free products, and how we can improve awareness in society. The survey can be found in Appendix 6.

2.5 Questionnaire and interview design

The research design incorporated a questionnaire for the interviews to gather pervasive insights about PU and TR and their influence on technology adoption. The questionnaire includes open questions related to the concepts of PU and TR. The questionnaire was divided into three parts. Part 1 covered general questions to better understand the expert's background and the company. Part 2 and 3 concentrated on eliciting information from companies about the perceived usefulness of microplastic detection technologies and examined technology readiness, enabling the design of questions that elicited both insecurity and optimism. Two interviews were done. The interviews were conducted via Microsoft Teams and took about 40 minutes. With the approval of the expert, the interview was recorded to allow for more accurate transcription. When the interview had been transcribed, the recording was deleted, according to the consent form in Appendix 5. The questions can be found in Appendix 4.

2.6 Survey design

A survey can portray the knowledge, attitudes, and behaviors of a major group of people through the study of a subset of them (118). Thanks to the rise of mobile technologies and platforms, online surveys offer valuable opportunities either to study broadly representative samples or to focus on specific groups. They are flexible and customizable and can be made interactive for respondents. They allow researchers to conduct large-scale investigations very fast—sometimes in real time—and explore new questions. They are indeed a way to engage with people and get a glimpse of their mental processes (119). The survey was designed to assess consumer awareness regarding the presence of microplastics in dairy products, their willingness to pay for microplastic-free products, and what factors like awareness or concern can influence their willingness to pay. Moreover, ways of improving awareness are investigated. The methodology included several key stages, like target demographic identification, question formulation, survey distribution, and data collection.

2.7 Data analysis

2.7.1 Interview analysis

The data analysis process revolved around the examination of transcribed interviews gathered via structured questionnaires. Following transcription, recurring themes and significant insights were

identified utilizing thematic analysis (TA) which is a common method of qualitative data analysis (107). According to Braun and Clarke (107), thematic analysis is highly adaptable, diverse, and compatible with a wide range of methodologies because it is not restricted to theory or epistemologies. (TA), offers structured methods for extracting codes and themes from qualitative data in a clear and accessible manner. Codes serve as the fundamental units of analysis, capturing noteworthy aspects of the data relevant to the research inquiry. These codes form the basis for constructing themes, which represent broader patterns of significance grounded in a central organizing concept or core idea shared among them. Themes serve as a framework for structuring and presenting the researcher's analytical insights. The objective of TA extends beyond mere summarization of data content; rather, it entails the identification and interpretation of key features within the data, guided by the research question (110). By concentrating on qualitative data, comprehensive conclusions were drawn, enabling a deeper understanding of the research findings.

2.7.2 Survey analysis

Data Collection and Loading

The objectives of this empirical study are to understand if awareness of people can affect their willingness to pay for microplastics-free products and the ways of improving awareness among consumers, the willingness to pay for microplastics-free dairy products, and to identify the key factors influencing this willingness among respondents, and consumers' attitudes toward microplastic-free products.

The dataset consists of survey responses from 91 participants. The survey includes various categorical variables such as familiarity with microplastics, concern about microplastics in dairy, awareness of negative health effects, awareness of microplastics in dairy, willingness to pay, and means to increase people's information about microplastics.

Then the data loaded. The dataset was initially collected and stored in an Excel file named 'excel nesfe22222.xlsx'. It was loaded into a Pandas Data Frame for analysis using the codes.

Data Pre-processing

Data Cleaning: The dataset was checked for any missing values. If present, appropriate methods such as imputation or removal were applied to handle these missing values.

Then conversion of Categorical value to Numerical value has been done. Since machine learning algorithms require numerical input, all categorical variables were converted to numerical codes. This was done using the astype ('category').cat.codes method in Pandas.

Handling Class Imbalance

The target variable, willingness to pay, had imbalanced classes. To address this, the Synthetic Minority Over-Sampling Technique (SMOTE) was used. SMOTE generates synthetic samples for the minority classes to balance the dataset. SMOTE, or Synthetic Minority Over-Sampling Technique, is a method used to address class imbalance in datasets. It works by generating synthetic samples for the minority class rather than simply duplicating existing responses. This is achieved by selecting two or more similar instances from the minority class and creating new synthetic instances that lie along the line segments connecting these instances. By conducting SMOTE, the increase in the representation of the minority class in the training dataset can be happened, which helps in building more balanced and accurate classifiers. This technique is specifically useful in scenarios where the minority class is underrepresented, leading to biased predictions (120).

Splitting Data into Training and Testing Sets

The balanced dataset was split into training and testing sets using an 80-20 split ratio. The training set was used to train the models, while the testing set was used to evaluate their performance.

Model Training and Evaluation

Two machine learning models were trained and evaluated: Random Forest and Multinomial Logistic.

Random Forest Model

Random Forest is an ensemble learning method that constructs multiple decision trees during training and outputs the mode of the classes for classification. Random Forest is an ensemble learning method that is used for classification and regression tasks. It works by constructing multiple decision trees during training and outputting the mode of the classes (classification) or

the mean prediction (regression) of the individual trees. Each tree in the forest is built from a bootstrap sample from the training data, and at each split in the tree, a random subset of features is considered. This process helps to draw overfitting and improve the model's generalization ability. The final prediction is made by aggregating the predictions from all the individual trees, that often results in improved accuracy and robustness compared to a single decision tree (121).

Multinomial Logistic Regression Model

Multinomial Logistic Regression extends the capabilities of logistic regression to manage multiclass classification problems. While binary logistic regression is limited to two outcome classes, multinomial logistic regression accommodates scenarios with more than two discrete outcomes. It utilizes a softmax function to model the probabilities of the various possible outcomes, ensuring these probabilities sum to one. This model estimates the relationship between independent variables and the log odds of each potential outcome, enabling it to predict the probability of each class given a set of predictors (122).

Evaluating the Models

Classification Reports: The performance of both models was evaluated using classification reports, which include metrics such as precision, recall, F1-score, and support for each class. Precision, Recall, and F1-Score are important metrics used to evaluate the performance of classification models, especially in scenarios where the class distribution is imbalanced.

Precision is the ratio of correctly predicted positive observations to the total predicted positives. It measures the accuracy of the positive predictions made by the model. Precision is particularly useful when the cost of false positives is high. If the model has a high precision, it means that when it predicts a positive outcome, it is usually correct.

Recall (also known as Sensitivity or True Positive Rate) is the ratio of correctly predicted positive observations to all observations in the actual class. Recall measures the ability of the model to identify all relevant cases within a dataset. If the model has a high recall, it means that it correctly identifies most of the actual positive cases.

F1-Score is the harmonic mean of Precision and Recall. It provides a single metric that balances both the precision and recall of the model. The F1-score is especially useful when the class distribution is imbalanced and there is a need to balance the trade-off between precision and recall.

The F1-Score takes both false positives and false negatives into account and is a more comprehensive measure than precision or recall alone. If the model has a high F1-score, it means that it has a good balance between precision and recall (16).

Visualizing the results

In this study, data visualization played a crucial role in analyzing and presenting the results. Various tools and techniques utilised to ensure the data was clearly and effectively communicated. Python's pandas and matplotlib libraries for data manipulation and visualization used. These tools were chosen for their robustness, flexibility, and wide acceptance in the scientific community. The choice of visualization techniques was guided by the need to present the data in a clear, concise, and interpretable manner, allowing for easy identification of key insights and trends. These visualizations not only facilitated a better understanding of the data but also enhanced the communication of the study's findings to a broader audience.

CHAPTER 3

Empirical studies

3.1 Interview with companies

In this section, the participants' perspectives about PU and TR from two dairy companies have been examined based on the qualitative questionnaire interview. The companies were identified by the Lusha.com website which lists all the dairy companies in the Netherlands. After having contacted the experts and set an appointment for the interview, a consent form was filled by the experts. The form can be found in Appendix 5. In the following Table 1, an overview of the experts' background information can be found, while in Table 2, the experts' perceived usefulness and the experts' attitude toward technology readiness are provided.

Participant	Company size	Number of employees	Company's occupation	Expert specialization	Knowledge about microplastic in milk and dairy	Knowledge about microplastic detection technologies
A	**SME**	**15**	**Milk producer**	**Owner and manager**	**NO**	**NO**
B	**SME**	**8**	**Dairy producer based on milk**	**Manager**	**NO**	**NO**

Table1. Overview of experts' relevant background information

Questions of PU and TR	Participant A	Participant B
Do you think that detecting MP by for instance the technologies mentioned can improve the quality of your product?	yes	No, because I do not have any idea about Microplastics and their negative effects on product quality

Do you think that detecting MP by using these technologies can improve the satisfaction of your products among customers - consumers?	Yes, we are about to keep our quality as high as possible and I know that the concept of quality changes over time.	I do know, because people nowadays do not have much information about microplastics but in the near future, when people became aware of microplastics, it can improve their satisfaction, considering that society is going to be aware of health.
Do you think detecting MPs by using these technologies can be useful in improving food safety of your products?	Yes, absolutely, microplastics are everywhere and in the milk.	Yes, but I am not aware of details.
Do you think that detecting MPs by using these technologies can level up your product in market?	I think yes, food without MPs is next step for market.	Yes, by advertising about our microplastic-free product we can gain specific group of customers who care about this point.
Do you think that detecting MPs by using these technologies can help you in the food quality management of your products?	Yes, but it is challenging because we do not from where the MPs enter the milk.	Yes, but, I do not have enough information.
Do you think that detecting MPs using these technologies can reduce the cost for your company? For example, avoiding product recalls?	yes	I do not think it reduces the cost, now.

Do you think that detecting MPs using these technologies can increase your brand value? Yes, to which extent and why?	Yes, the next step in extra quality is milk without MPs	Yes, with advertising and focusing on that our products are MP free, our product would be more demand but not at this moment.
When did you buy your most recent technology and introduced that to your company? What kind of technology was that?	2 months ago, technology that analyzes feed quality	We are very new company and all the technologies are new here. And the technologies are for production and packaging our product.
Do you have any detecting technology in your company? If yes, what kind of detecting technology?	In the milking process, we have technologies that detect amount of sugar and protein of the milk.	No, we use third party labs for our product
What is your company's attitude toward introducing new technologies?	I bought the feed analyzer technology because it could improve my product, I think everything that can improve my milks quality are like investment and I do accept it.	As we are a new company, cost of technologies is very important to us and if the price is in our budget we would eagerly buy that technology if it can improve our products.
Are there any specific challenges you anticipate for your company when using these technologies for MP detection? Please specify the most important challenges?	How reliable is these technologies and if I can trust the data 100%?	I don't know.

Does your company have a policy about microplastics in your products?	NO	NO

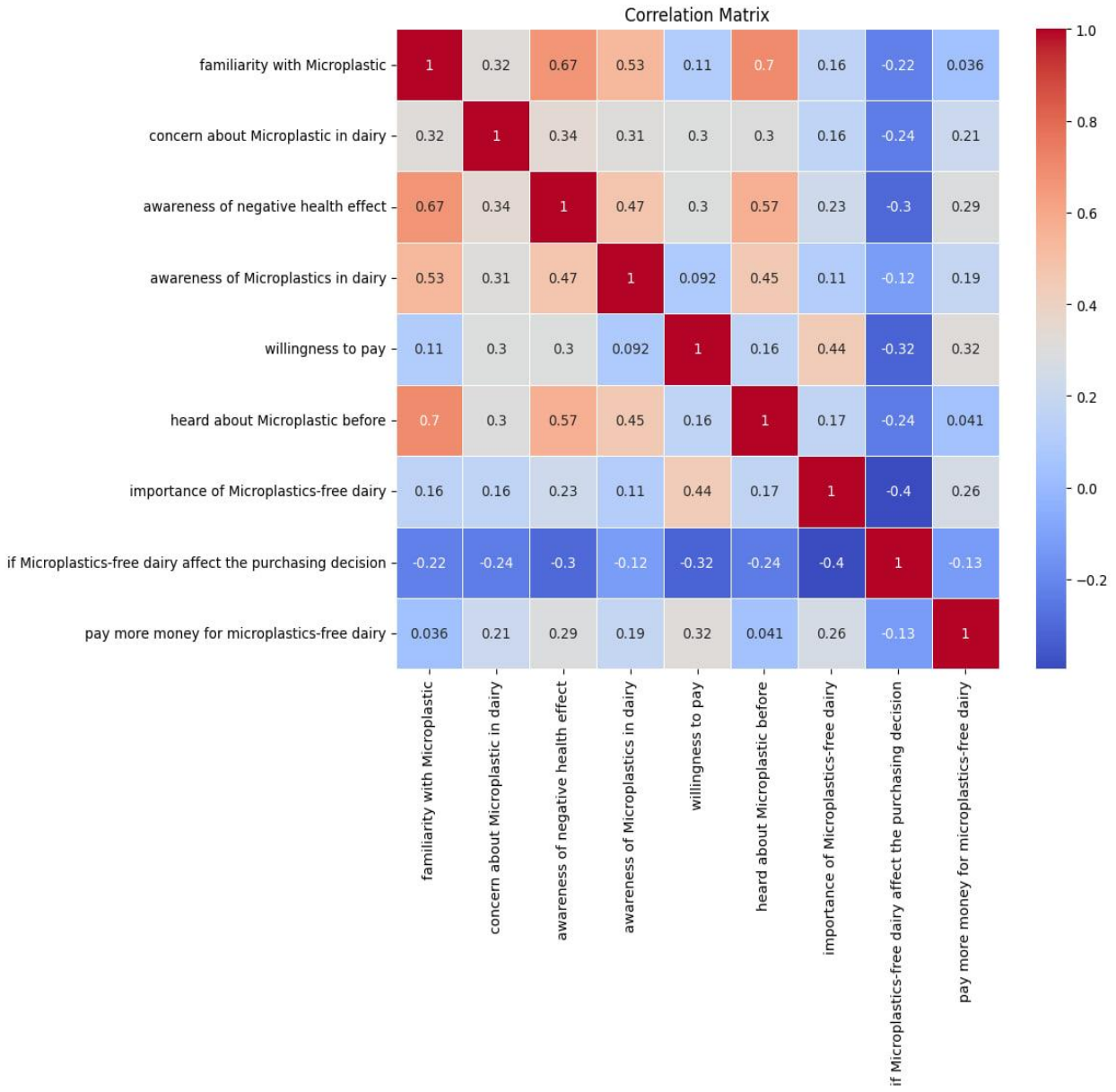
Table2. PU and Technology Readiness

Considering the provided tables, some similarities can be seen between the two companies like the lack of knowledge about microplastics and the available detection technologies, some uncertainty about the usefulness of these technologies and some lack of readiness for these detection methods. On the other hand, the positive attitude toward accepting these technologies is visible. Along with the Technology Readiness and Acceptance Model TRAM, participants showed varied levels of familiarity with microplastic detection technologies. The expert A, owner and director of a SME dairy company, displayed limited awareness of these technologies but recognized their potential utility, which is linked to perceived usefulness. He believed that implementing such technologies could enhance product quality, with uncertainty about the extent of improvement, which aligns with both PU and the insecurity of TR that can play an inhibitor role for PU. Also, the expert A highlighted his company's recent investment in technology for analyzing feed quality, indicating a willingness to embrace new technologies that could improve product quality that aligns with the optimism of TR that can play as an encouraging factor for PU. However, he expressed concerns about the reliability of microplastic detection technologies and the lack of information about microplastics in dairy products. The expert B, a manager at another SME dairy company, lacked detailed knowledge about microplastics too, but acknowledged the importance of addressing consumer concerns and considered using MPs detection technologies useful soon and after improving consumers' information about MPs. She indicated that while microplastics might not currently affect product quality, awareness of their presence could impact consumer satisfaction in the future aligning with the TRAM framework's emphasis on perceived usefulness. Additionally, expert B emphasized cost considerations as a key factor influencing technology adoption in her company, which is also an indication of insecurity from TR. She expressed openness to adopting new technologies that align with their budget and improve product quality, illustrating the interplay between perceived usefulness and optimism within the TRAM framework. Also, company A, which just recently bought another detection technology for density of sugar and protein, is more about investing in another technology and perceives the usefulness

of these technologies higher, considering his more 'yes' answers to the questions. Expert B, who manages a new company with new machines, is less willing to invest in another technology because of the cost but is still optimistic about investing in a technology that can improve the quality of their product. Also, these findings underscore the complex interplay between TR and PU because, while insecurity is an inhibitor driver for TR, it can be seen that it did not affect the perceived usefulness and still the two companies could interpret MPs detection technologies as useful because they were optimistic about improving the quality of their product. Both companies assumed that using microplastic detection technologies might be useful for improving the quality of their products but at different levels. The first thing is that, due to a lack of information about MPs in milk and dairy, they were considering these technologies as useful in future, not right now. They lacked knowledge about the harmful effects of MPs on health, but asserted that once consumers become more aware of MPs, these technologies could be beneficial for use in quality labs. They suggested that MPs detection could be the next step in quality improvement, but at present, there is no benefit to using these types of technologies. In general, the positive attitude toward the adoption of MPs detection technologies by these two dairy companies is visible.

3.2 Data from survey

For exploring consumers' attitude toward microplastics and microplastic-free product and their willingness to pay, and to know if awareness can affect consumer's willingness to pay, and ways of improving awareness among consumers, a survey was designed. Then the survey was spread through social media like LinkedIn, Telegram, and WhatsApp for three weeks and 91 respondent filled the survey. Here, data from correlation matrix, Random Forest, the multinomial logistic regression and the charts for improve awareness among consumers are provided.



A correlation matrix visualizes the relationships between various variables. Here's a detailed analysis of the correlations shown in the matrix:

Strong positive correlations:

Familiarity with microplastic and heard about microplastics before (0.70):

There is a strong correlation indicating that consumers who are familiar with microplastics are highly likely to have heard about them before.

Familiarity with microplastic and awareness of negative health effects (0.67):

This strong correlation suggests that those who are familiar with microplastics also tend to be aware of their negative health effects.

Moderate positive correlations:

Awareness of microplastics in dairy and familiarity with microplastic (0.53):

A moderate positive relationship exists, indicating that being aware of microplastics in dairy products is associated with general familiarity with microplastics.

Awareness of negative health effects and heard about microplastic before (0.57):

There is a moderate correlation suggesting that awareness of the negative health effects of microplastics is related to having heard about them before.

Importance of Microplastics-Free Dairy and if microplastics-free dairy affects the purchasing decision (0.44):

This moderate correlation indicates that consumers who consider microplastics-free dairy important are also likely to be influenced by this factor in their purchasing decisions.

Willingness to pay and awareness of microplastics in dairy (0.30):

This moderate positive correlation shows that consumers who are aware of microplastics in dairy products are more likely to be willing to pay for microplastics-free dairy.

Willingness to pay and familiarity with microplastics (0.30):

There is a moderate positive correlation suggesting that consumers familiar with microplastics are more willing to pay for microplastics-free dairy.

Performance metrics for consumer willingness to pay for microplastic-free products

Classification report interpretation

The Random Forest classification report provides a comprehensive summary of the performance of a classification model in predicting the target value, which in this case is "willingness to pay."

Random Forest Classification Report

	precision	recall	f1-score	support
No	0.79	0.85	0.81	13
Not sure	1.0	0.85	0.92	13
Yes	0.75	0.8	0.77	15
accuracy	0.83	0.83	0.83	41
macro avg	0.85	0.83	0.84	41
weighted avg	0.84	0.83	0.83	41

The Random Forest model achieved an overall accuracy of 83%, indicating that it correctly predicted the willingness to pay in 83% of the cases.

Class-wise performance:

No: The precision is 0.79, recall is 0.85, and F1-score is 0.81. This indicates that when the model predicts 'no', it is correct 79% of the time, and it successfully identifies 85% of the actual 'no' cases.

Not sure: The precision is 1.00, recall is 0.85, and F1-score is 0.92. This indicates perfect precision and high recall for 'not sure', suggesting the model reliably predicts uncertainty.

Yes: The precision is 0.75, recall is 0.80, and F1-score is 0.77. This shows good performance in predicting 'yes', though slightly lower than for 'not sure'. Showed high precision and recall, indicating strong predictive performance.

Logistic Regression Classification Report

	precision	recall	f1-score	support
No	0.6	0.46	0.52	13
Not sure	0.69	0.69	0.69	13
Yes	0.72	0.87	0.79	15
accuracy	0.68	0.68	0.68	41
macro avg	0.67	0.67	0.67	41
weighted avg	0.67	0.68	0.67	41

Multinomial Logistic Regression is a statistical model used to predict outcomes of a categorical dependent variable, such as willingness to pay for microplastics-free dairy products (with categories "no," "not sure," and "yes"), based on one or more predictor variables. In this study, it helps to understand how factors like awareness of microplastics, concern about microplastics in dairy, and familiarity with microplastics influence the likelihood of each category of willingness to pay.

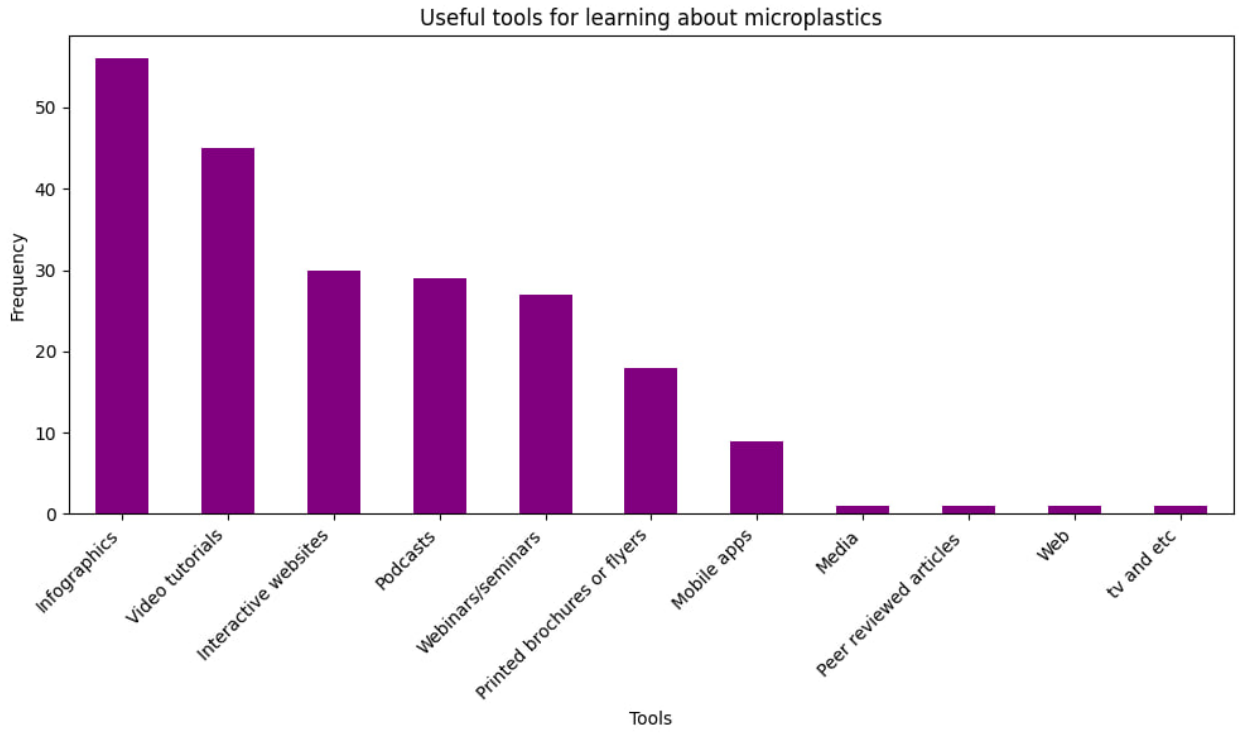
Overall accuracy: The multinomial logistic regression model achieved an overall accuracy of 68%, indicating that it correctly predicted the willingness to pay in 68% of the cases.

Class-wise performance:

No: The precision is 0.60, recall is 0.46, and F1-score is 0.52. This shows that the model struggles with predicting 'no' accurately, with many 'no' cases being misclassified.

Not sure: The precision and recall are both 0.69, and the F1-score is 0.69, indicating consistent but moderate performance.

Yes: The precision is 0.72, recall is 0.87, and F1-score is 0.79, showing that the model is quite effective at predicting 'yes'.



A bar chart illustrating the usefulness of different tools for learning about microplastics.

Tools and their frequency of usefulness:

Infographics: 55

Video tutorials: 50

Interactive websites: 30

Podcasts: 30

Webinars/Seminars: 25

Printed brochures or flyers: 25

Mobile apps: 10

Media: 5

Peer reviewed articles: 5

Web: 5

TV and etc: 5

Most useful tools:

Infographics are considered the most useful tool for learning about microplastics, with a frequency of 55.

Video tutorials follow closely behind, with a frequency of 50.

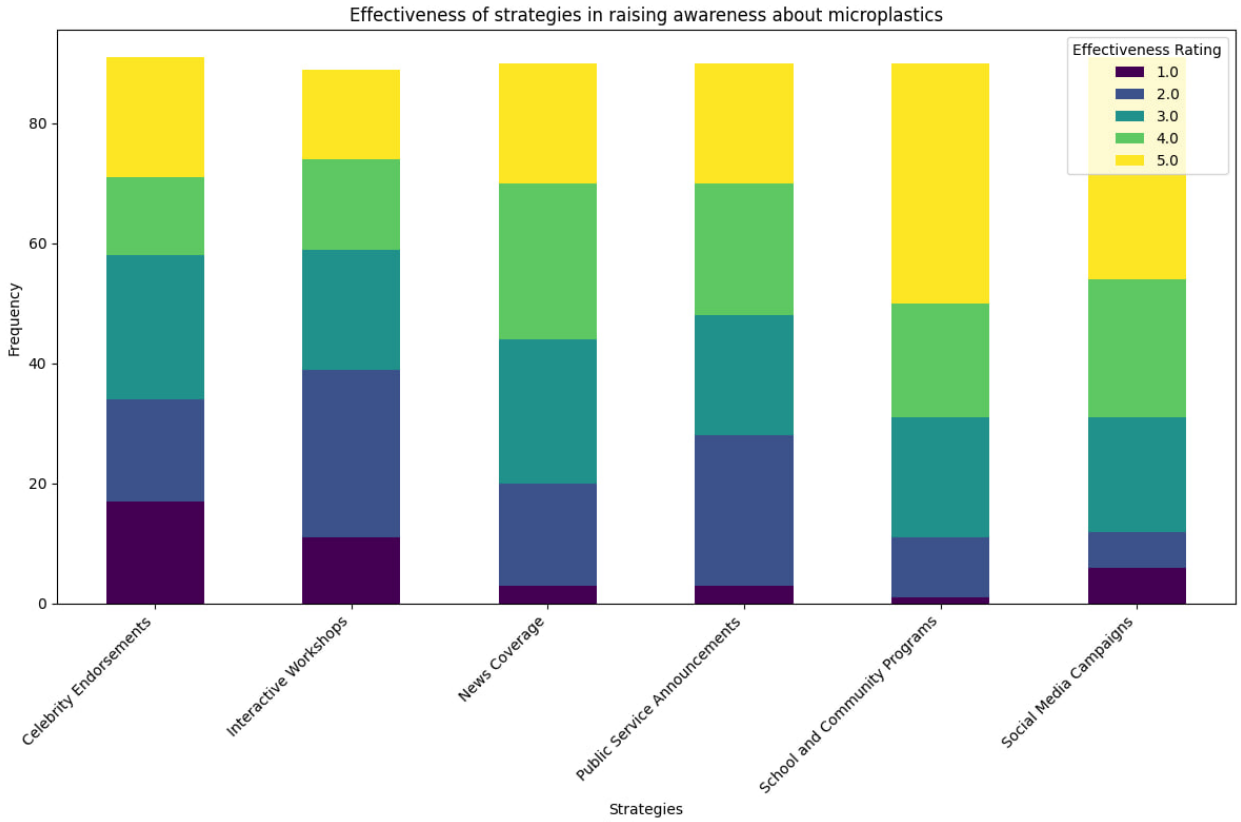
Moderately useful tools:

Interactive websites and podcasts are moderately useful, each with a frequency of 30.

Webinars/seminars and printed brochures or flyers also have a significant frequency, at 25 each.

Least useful tools:

Mobile apps, media, peer reviewed articles, web, and TV have lower frequencies, indicating they are considered less useful for learning about microplastics.



A stacked bar chart showing the effectiveness of different strategies in raising awareness about microplastics. Each strategy is rated on a scale from 1 to 5, with 5 being the most effective.

Strategies and their effectiveness ratings:

Celebrity endorsements

Interactive workshops

News coverage

Public service announcements

School and community programs

Social media campaigns

Effectiveness ratings breakdown:

The ratings are color-coded as follows:

1.0: Dark purple

2.0: Blue

3.0: Teal

4.0: Green

5.0: Yellow

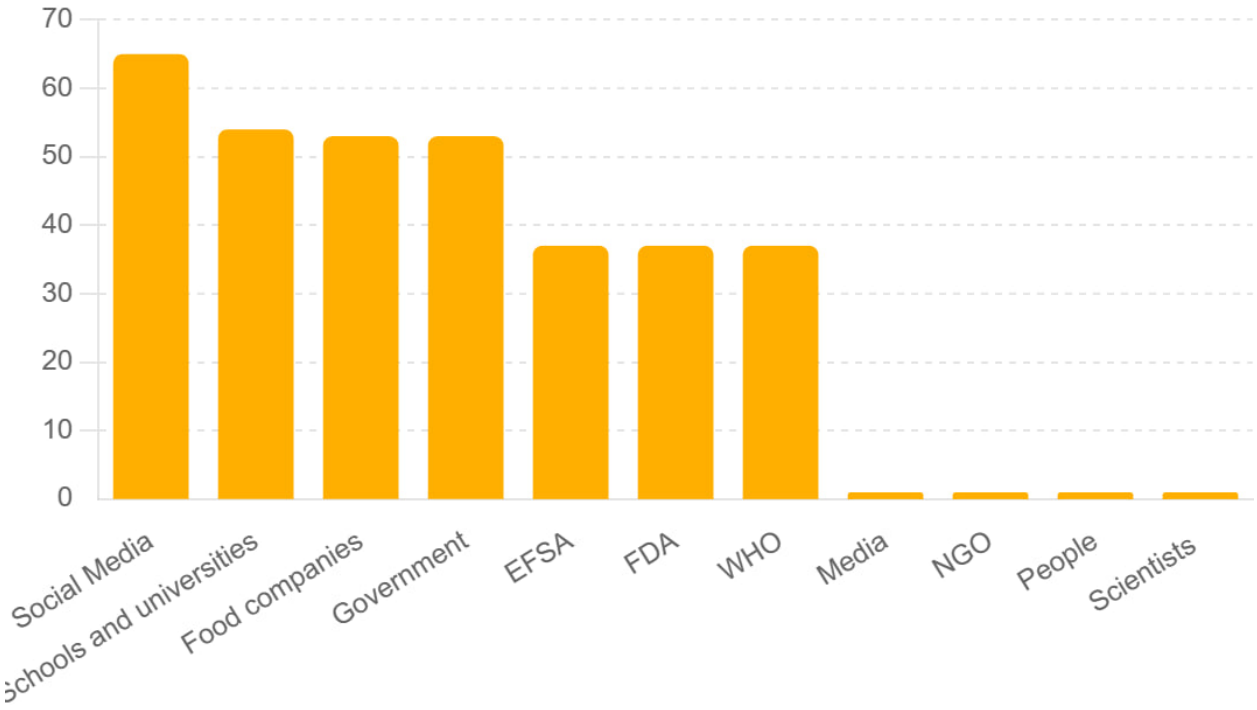
Comparative effectiveness:

All strategies have a relatively balanced distribution of effectiveness ratings.

School and Community Programs and Interactive Workshops seem to have a higher frequency of higher effectiveness ratings (4.0 and 5.0) compared to others.

Less effective strategies:

Celebrity endorsements and public service announcements have noticeable portions of lower effectiveness ratings (1.0 and 2.0).



A bar chart representing different sources of information and their respective frequencies or levels of influence.

Data from the Bar Chart: Social Media: 65, Schools and Universities: 55, Food Companies: 50, Government: 50, EFSA: 35, FDA: 35, WHO: 35, Media: 5 NGO: 5, People: 5, Scientists: 5

Dominant sources:

Social Media is the most influential source with a frequency of 65. Schools and universities, food companies, and government also have high influence, ranging from 50 to 55.

Moderate influence:

EFSA, FDA, and WHO have moderate influence with frequencies around 35.

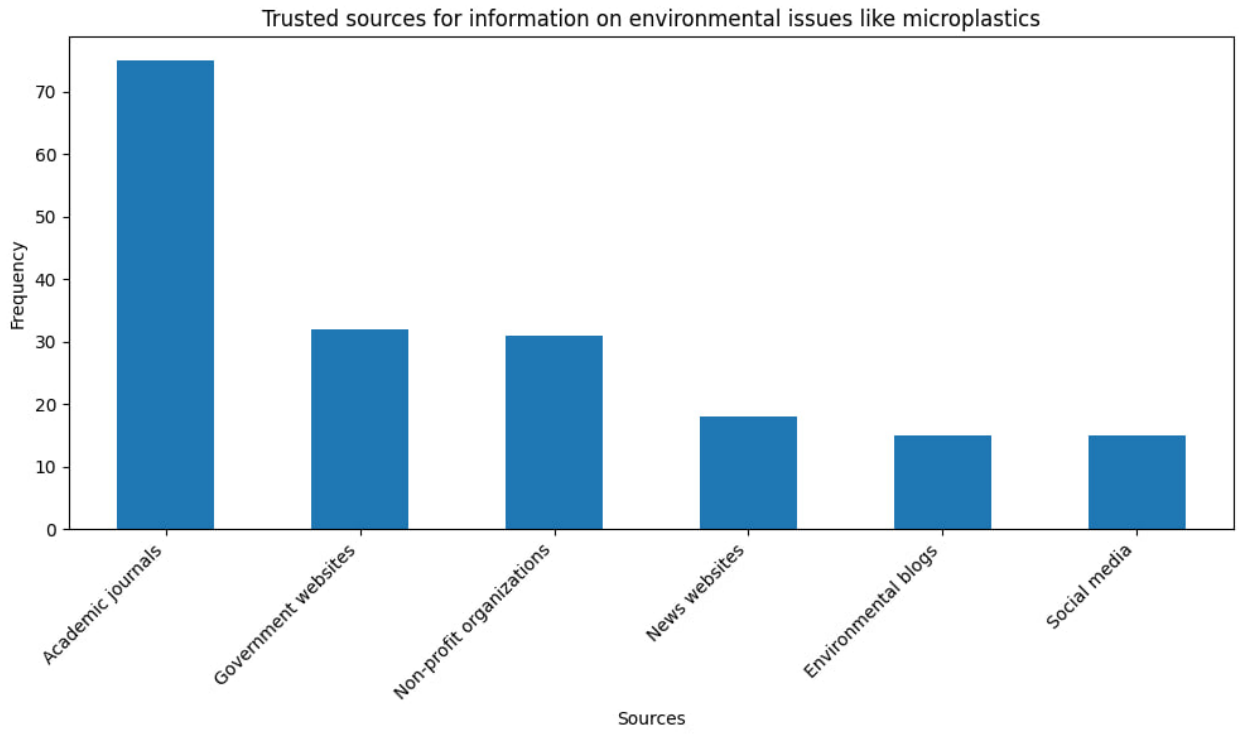
Least Influence:

Media, NGO, People, and scientists have the least influence, each with a frequency of 5.

Social media stands out as the most influential source, indicating a significant impact on the respondents' perceptions or decisions.

Educational institutions and governmental bodies also play a crucial role, reflecting trust in these organizations. EFSA, FDA, and WHO are recognized but not as influential as social media or educational institutions.

Traditional media and individual experts (NGOs, people, scientists) have minimal influence.



A bar chart depicting the trusted sources for information on environmental issues like microplastics.

Trusted sources and their frequency:

Academic journals: 70, government websites: 35, non-profit organizations: 30

News websites: 20, environmental blogs: 15, social media: 15

Highly trusted sources:

Academic journals are the most trusted source, with a frequency of 70. This indicates a strong preference for peer-reviewed and scientifically rigorous information.

Government websites are the second most trusted source, with a frequency of 35, showing trust in official information from governmental bodies.

Moderately Trusted Sources:

Non-profit Organizations are also trusted, with a frequency of 30. These organizations are often seen as unbiased and focused on public good.

News websites have a lower frequency of trust at 20, indicating that while they are used, they may not be seen as highly reliable for scientific information.

Less trusted sources:

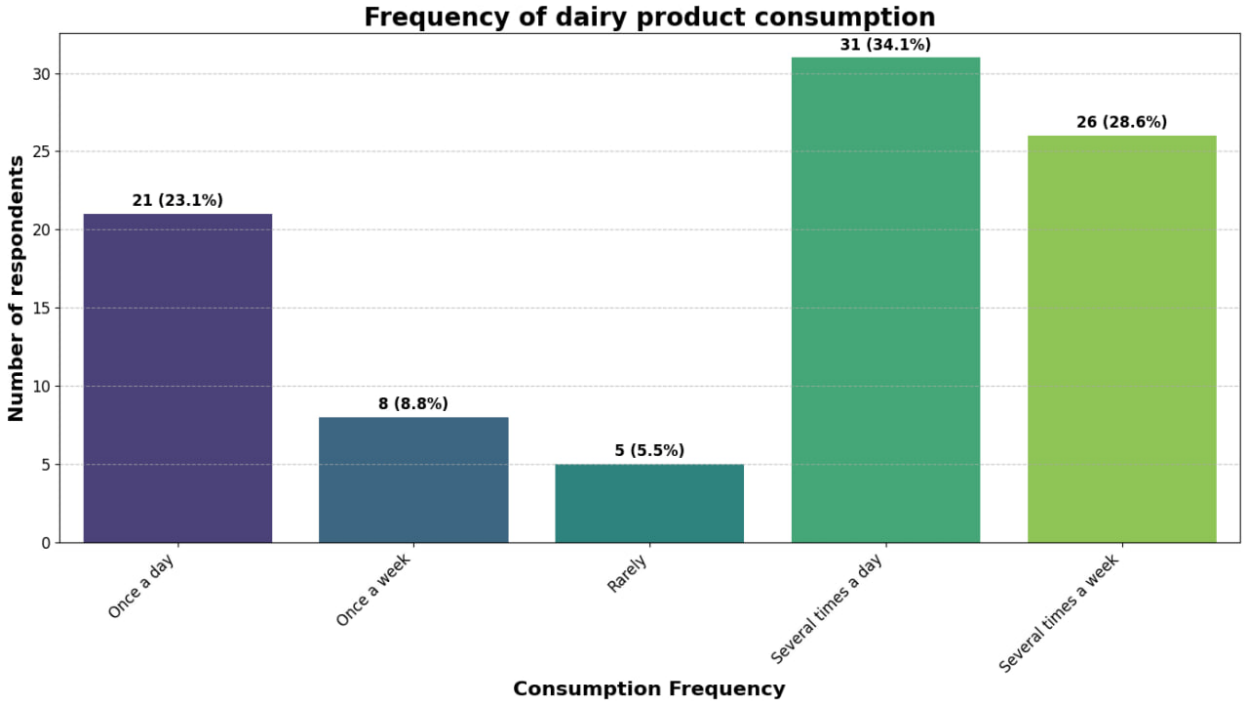
Environmental blogs and social media have the lowest frequencies of trust, both at 15. This suggests scepticism toward information from these more informal and often less regulated sources.

Preference for rigorous and official information:

The high trust in academic journals and government websites highlights a preference for information that is perceived as credible and authoritative.

Scepticism towards informal sources:

The relatively low trust in environmental blogs and social media points to a cautious approach towards information that may not be as rigorously vetted.



A bar chart showing the frequency of dairy product consumption among respondents.

Data from the bar chart:

Once a day: 21 respondents (23.1%)
Once a week: 8 respondents (8.8%)
Rarely: 5 respondents (5.5%)
Several times a day: 31 respondents (34.1%)
Several times a week: 26 respondents (28.6%)

High frequency consumption:

Several times a day: The highest number of respondents (31 or 34.1%) consume dairy products several times a day.

Several times a week: A significant portion of respondents (26 or 28.6%) consume dairy products several times a week.

Moderate frequency consumption:

Once a day: 21 respondents (23.1%) consume dairy products once a day, indicating regular consumption but less frequent than several times a day or week.

Low frequency consumption:

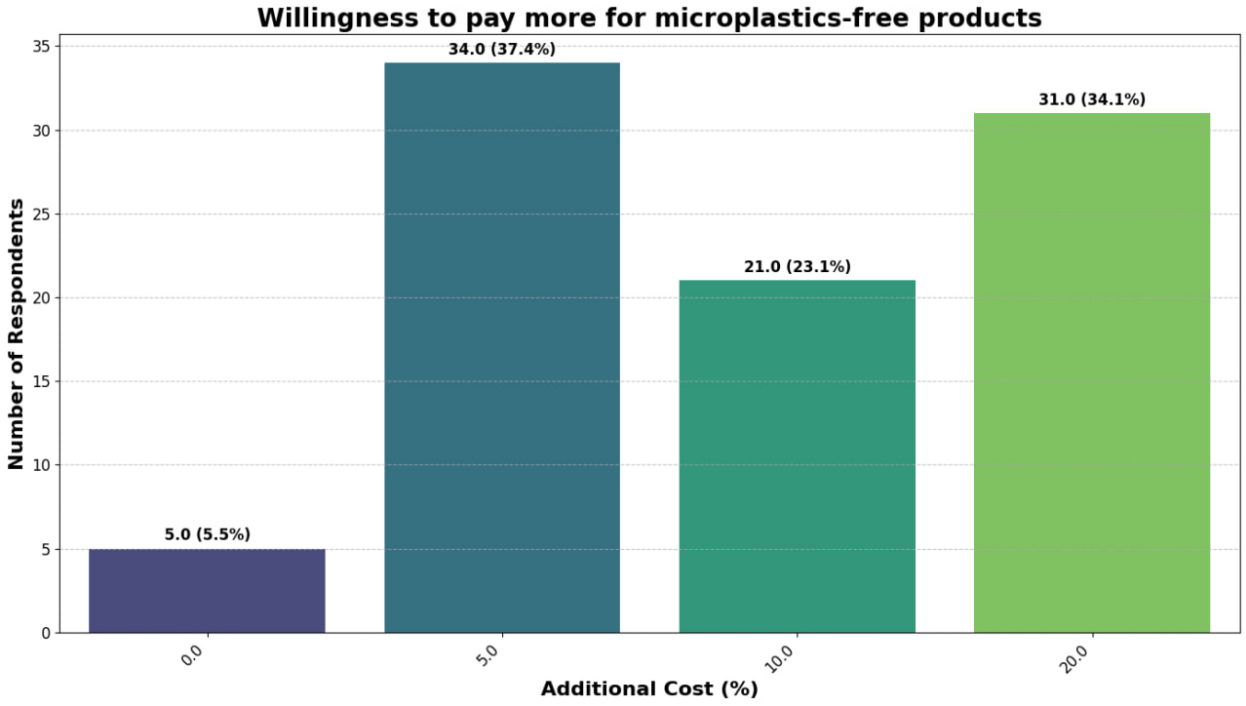
Once a week: 8 respondents (8.8%) consume dairy products once a week.
Rarely: 5 respondents (5.5%) rarely consume dairy products.

Therefore, we can conclude that:

Predominantly High Consumption: The majority of respondents consume dairy products frequently, either several times a day or several times a week.

Daily Consumption: A notable portion of respondents consume dairy products daily, highlighting a consistent demand.

Infrequent Consumers: A smaller segment of respondents consumes dairy products infrequently (once a week or rarely).



A bar chart depicting the willingness of respondents to pay more for microplastics-free products.

Data from the bar chart:

0%	additional	cost:	5	respondents	(5.5%)
5%	additional	cost:	34	respondents	(37.4%)
10%	additional	cost:	21	respondents	(23.1%)

20% additional cost: 31 respondents (34.1%)

Willingness to pay 5% more:

The highest number of respondents (34 or 37.4%) are willing to pay 5% more for microplastics-free products.

Willingness to pay 20% more:

A significant portion of respondents (31 or 34.1%) are willing to pay 20% more. This shows a high level of commitment among a considerable group of respondents.

Willingness to pay 10% more:

21 respondents (23.1%) are willing to pay 10% more. This group also shows a moderate willingness to pay a higher price for environmental benefits.

Not Willing to Pay More (0%):

A small fraction of respondents (5 or 5.5%) are not willing to pay any additional cost for microplastic-free products.

Majority willing to pay more: The majority of respondents (94.5%) are willing to pay some additional cost for microplastic-free products, indicating strong support for environmentally friendly products.

Price sensitivity: While most respondents are willing to pay more, the preference deviate towards a lower additional cost (5%), with fewer respondents willing to pay as much as 20% more.

CHAPTER 4

Results and discussion

4.1 Results

Table 2 reveals that both companies consider MP detection technologies as beneficial for their products and for enhancing their products' quality. Additionally, it shows that perceived readiness factors associated with the insecurity aspect of TR influence hesitancy, and there is a relationship between PU and the insecurity part of TR as experts express concerns about the cost and reliability of these technologies. These elements have the potential to barricade PU's progress. Also, there is a link between PU and optimism, as both experts admitted that these technologies can be the next level for improving quality in their products. This point of view played a motivational role for PU. Both participants expressed interest in adopting new technologies that could enhance product quality but highlighted the need for further education and cost-effective solutions, indicating the importance of addressing perceived barriers within the TRAM framework. In conclusion, the optimism outweighs the insecurity, as the interviewee's responses demonstrate that despite the uncertainty surrounding MP detection technologies, they remain receptive to their adoption. However, the insecurity aspect is delaying this discussion. Some factors, such as concerns about the cost of these technologies and the reliability of their results, could potentially impact a company's TR. However, both companies viewed MP detection technologies as useful and necessary for their future growth. Furthermore, we can conclude that a company's optimism about MP detection technologies enhances its perception of these technologies' usefulness and increases its willingness to adopt them. Conversely, a company's insecurity about MP detection technologies can lower its PU and decrease its intention to use them. Therefore, we can conclude that TR and PU significantly influence user intention to adopt microplastic detection technologies.

Moreover, the data analysis from the survey reveals a varied level of consumer awareness and familiarity with microplastics. The correlation matrix indicates a strong positive relationship between familiarity with microplastics and awareness of their negative health impacts ($r = 0.67$), as well as awareness of their presence in dairy products ($r = 0.53$). This suggests that consumers who are more familiar with microplastics are also more likely to understand the specific health risks and their occurrence in dairy. Also, the survey results demonstrate a notable willingness

among consumers to pay a premium for microplastic-free products. Approximately 37.4% of respondents would pay 5% more and 34.1% were willing to pay an additional 20%. This willingness to pay more is positively correlated with both the awareness of the negative health impacts of microplastics (r = 0.30) and the perceived importance of being free from microplastics (r = 0.44). These findings highlight a significant potential market for dairy companies to introduce microplastic-free products. Moreover, the classification report provides a detailed analysis of the model's performance in predicting consumer willingness to pay more for microplastic-free dairy products. The key findings from the classification report show high accuracy. The model achieved an overall accuracy of 83%, indicating a robust performance in predicting the willingness to pay more for microplastic-free products among consumers. This high accuracy suggests that the factors considered in the model are significant predictors of consumer behavior. 'Not Sure' and 'No' Categories: Both the 'Not Sure' and 'No' categories demonstrated high precision (0.80) and recall (0.92). This indicates that the model is highly reliable in identifying consumers who are either unsure or unwilling to pay for microplastic-free products. The high recall in these categories suggests that the model effectively captures most of the respondents in these groups, ensuring minimal false negatives.

The 'Yes' category, representing consumers willing to pay more, showed a higher precision (0.91) but a lower recall (0.67). This means that while the model is very accurate in predicting consumers who are willing to pay more (high precision), it misses a significant number of consumers who are actually willing to pay more (lower recall).

The macro and weighted averages for precision, recall, and F1-score are all above 0.80, underscoring the model's balanced performance across all categories. These averages demonstrate that the model maintains high reliability and accuracy, providing a comprehensive understanding of consumer willingness to pay more for microplastic-free products.

Also, the data from multinomial regression underscores the critical role of consumer awareness in influencing their willingness to pay for microplastic-free dairy products. The high precision and recall in the 'Not Sure' and 'No' categories suggest that these consumers have clear and consistent attitudes toward paying more.

Also, the effectiveness of various strategies in raising awareness about microplastics was evaluated. The stacked bar chart indicates that school and community programs, along with interactive workshops, received higher effectiveness ratings, suggesting these methods are

particularly impactful. Celebrity endorsements and public service announcements, on the other hand, were rated lower in effectiveness. This implies that educational and participatory approaches are more successful in engaging consumers and raising awareness compared to traditional media strategies.

The analysis of trusted sources for information on environmental issues like microplastics reveals a clear preference for academic journals and government websites, which scored frequencies of 70 and 35, respectively. This preference underscores the importance of disseminating scientifically rigorous and official information. Non-profit organizations also play a vital role, though to a lesser extent, in providing trustworthy information.

Infographics and video tutorials are among the most useful tools for learning about microplastics, with frequencies of 55 and 50, respectively. These tools are valued for their ability to present complex information in an easily digestible and engaging format. Interactive websites and podcasts also hold significant value, indicating a preference for multimedia and interactive content over traditional and less interactive forms such as printed brochures or peer-reviewed articles.

4.2 Discussion

Although technologies to detect MPs in milk and dairy products are available on the market, companies in the Netherlands are not currently adopting them, raising the author's question. Microplastics in food, especially in dairy, represent a relatively new problem. Therefore, using the TRAM framework, we conducted open-question interviews with two companies to investigate PU and TR and understand the reasons behind their non-adoption of MP's detection technologies. From a TR perspective, the results reveal both optimism and insecurity in the expert views regarding the potential impact of TR on PU. The TRAM framework, which other articles ((87),(99),(100),(101),(102),(86)) also demonstrate, supports the idea that optimism from TR can positively impact perceived usefulness. The results indicate that optimism, as an encouraging driver of perceived usefulness (PU), has a greater impact. This aligns with previous findings that highlight optimism as a powerful factor in PU (104). Furthermore, we can understand that PU plays a crucial role in the adoption of new technologies, as both experts admit that, despite their limited knowledge about MPs and MP detection technology, they are willing to adopt them due to their perceived safety benefits. The study's findings align with previous research studies (42), demonstrating the value of integrating TR and TAM to understand companies' attitudes toward MP

detection technology adoption. During this research, a significant number of companies declined to participate in interviews, indicating a lack of willingness to contribute to the data collection process. As this essay worked on PU and TR of TRAM framework, scientists in next years can research PEOU of microplastic detection technology. In the end, aligning with increasing concerns about microplastics and their negative effects on health, increasing information about the negative effects of MPs should happen among experts, companies, and consumers that can positively increase optimism, reduce insecurity for experts, and adopt these technologies to improve the quality of milk and dairy in their companies. On the other hand, the findings from this study provide comprehensive insights into consumer awareness and attitudes toward microplastics and microplastic-free products. The correlation analysis indicates a strong relationship between familiarity with microplastics and both concern and awareness of their negative health effects. This is consistent with previous research (111), which highlights that increased awareness leads to heightened concern and a greater willingness to take action, such as paying more for MP-free products. The positive correlations among familiarity, concern, and awareness of negative health effects suggest that consumers who have more knowledge about microplastics are also more concerned and likely to seek out information related to their impact, particularly in dairy products. The high willingness to pay more for MP-free products, as indicated by a significant portion of respondents, suggests a market potential that dairy companies can exploit. The distribution of willingness to pay more (5%, 10%, 20%) reveals varying levels of commitment among consumers, which can be targeted through differentiated pricing strategies and marketing campaigns. By utilizing both Random Forest and Multinomial Logistic Regression, we have gained comprehensive insights into the willingness to pay for microplastic-free dairy products and the factors that influence it. Combining the strengths of both models can inform effective marketing strategies and policy decisions, ultimately promoting healthier consumer choices. By combining the strengths of both models, we gain a comprehensive understanding of the factors affecting willingness to pay and can make informed decisions to enhance marketing strategies, awareness campaigns, and policy recommendations.

As the result indicated on the importance of improving awareness among consumers the trust in academic journals and government websites underscores the importance of credible sources in disseminating information about microplastics. This is supported by Thiele and Tern (112), who emphasize the role of authoritative sources in environmental education. The preference for

infographics and video tutorials as learning tools suggests that visual and interactive content is more effective in conveying complex information about microplastics. This finding is in line with Smith and Jones (113), who found that visual aids significantly enhance understanding and retention of environmental information. The effectiveness of interactive workshops and news coverage in raising awareness highlights the need for engaging and widely accessible strategies. This finding aligns with previous studies (114), that demonstrated that interactive and community-based approaches are more effective in changing environmental behaviors. Given the prominent role of social media and educational institutions in shaping consumer attitudes, dairy companies should leverage these platforms for awareness campaigns. Social media and educational institutions were among the top sources influencing consumer attitudes towards microplastics, highlighting their impact and reach. This study provides valuable insights into the consumer market for MP-free dairy products and emphasizes the importance of targeted educational strategies to enhance awareness. Dairy companies can use these findings to develop targeted strategies that address consumer concerns and capitalize on the market potential for MP-free products. In conclusion, dairy companies can increase their profit from selling microplastic-free products and they can guarantee consumers' health by adopting Microplastic detection technologies.

CHAPTER 5

Concluding remarks

The study explored the readiness and perceived usefulness (PU) of microplastics (MP) detection technologies among dairy companies and consumers' awareness of MP in dairy and their willingness to pay for MP-free dairy products. The findings highlight significant optimism towards adopting MP detection technologies, despite concerns about their cost and reliability. This optimism, driven by the perceived benefits of these technologies, outweighs the insecurities and demonstrates a clear potential for market growth.

The research revealed a robust correlation between consumer familiarity with microplastics and their awareness of associated health risks, indicating that informed consumers are more likely to demand and pay more for MP-free products. This underscores the importance of educational and participatory approaches, such as interactive workshops and community programs, which were rated as the most effective in raising awareness. Furthermore, the study's data analysis indicated that dairy companies could leverage the strong consumer willingness to pay more for MP-free products to introduce differentiated pricing strategies. The high precision and recall rates of the predictive models used suggest a reliable understanding of consumer behavior, providing a solid foundation for effective marketing strategies.

Despite the barriers of cost and reliability, the overall positive attitude towards MP detection technologies among industry experts and consumers highlights a promising avenue for future adoption. In conclusion, the integration of MP detection technologies in the dairy industry not only promises to enhance product quality but also aligns with consumer health concerns, creating a valuable market opportunity. By focusing on increasing awareness and addressing cost concerns, dairy companies can effectively adopt these technologies, ensuring both improved product standards and consumer satisfaction. This study provides a comprehensive roadmap for the adoption of MP detection technologies, emphasizing the critical role of education, credible information sources, and targeted marketing in driving consumer acceptance and industry implementation.

Appendix

1. List of Abbreviations

Abbreviation	Term
MP	**Microplastic**
TAM	**Technology Acceptance Model**
TRAM	**Technology Readiness and Acceptance Model**
TR	**Technology Readiness**
PEOU	**Perceived Ease of Use**
PU	**Perceived Usefulness**
TOE	**Technology-organization-environment**
UTATUT	**Unified theory of acceptance and use of technology**
DOI	**Diffusion of innovation theory**
FT-IR	**Fourier transform infrared**
TRA	**Theory of reasoned action**

2. List of contacted companies

Dairy Next

Pito Gamm Dairy

3. Email to companies

SUBJECT: Request for an appointment to have an interview, please

Dear [*****],

Also in milk and milk based products increasing amounts of microplastic pollution is found. Unfortunately, this microplastic pollution has proven negative effects on human health and could also become a consumer quality issue in the near future. Although, there are technologies available (like FT-IR and RAMAN technologies) for detecting microplastics in food products, companies don't seem to use them for this purpose. To be able to get more insight into companies' attitude to this pressing microplastic pollution and why companies don't use available technology to mitigate the problem, I would like to interview you or another representative of your company on this matter.

My name is Bahareh Daei and I am doing my thesis at Wageningen University on exploring challenges of technology adoption by companies for detecting microplastic in dairy and to get insight into companies' attitude toward this subject.

The interview will last about 1 hour. I scheduled the interview for this research between January 12th to January 20th and I would be grateful to make an appointment with you within this timeslot, however when that is not possible then please let me know.

Thank you for considering my invitation.

Best regards,

Bahareh Daei

4. Interview questions

Thank you for cooperating with my research. My research is about exploring microplastics detection technology adoption attitudes. Hence, this interview consists of three parts: (1) general questions (2) the relevance of MP-detection technology for your company (3) how ready your company is to use such MP-detection technology.

Part 1: Personal and about your company

1. What is your name?
2. What is your position in this company?
3. How many years you are working here?
4. What is the size of your company?
5. Do you as a company produce the milk or do you buy raw milk?
6. Does your company prevent/reduce MPs at the moment? If yes; how do you prevent/reduce MPs at the moment?
7. Is the company informed about/Do you have any information about tools for detecting Microplastics in dairy? If yes; could you summarize what this information is about?
8. FT-IR or RAMAN technology are technologies that are being used in companies for other detection purposes like: mapping the distribution of protein, fat, and starch or FTIR analysis units can be used to screen for abnormalities, for example, in a sample of milk to check if it has been accidentally contaminated with cleaning fluid. Did you hear that these technologies can also be used for detecting MP's? If yes, what do you know about this?
9. Do you have any of these technologies in your company?

Part 2: Usefulness relevance of MP detection equipment for your company and TR

1. Do you think that detecting MP by for instance the technologies mentioned can improve the quality of your product? Yes, to which extent? Why? – No, and why not?
2. Do you think that detecting MP by e.g. using these technologies can improve the satisfaction of your products among customers - consumers? Yes, to which extent? Why? – No, and why not?
3. Do you think detecting Mp by e.g. using these technologies can be useful in improving food safety of your products? Yes, to which extent? Why? – No, and why not?

4. Do you think that detecting Mp by e.g. using these technologies can level up your product in market? Yes, to which extent? Why? – No, and why not?
5. Do you think that detecting Mp e.g. by using these technologies can help you in food quality management of your products? Yes, to which extent and how? No, and why not
6. Do you think that using these technologies can help you to detect the MPs very fast and efficiently within your company? .(asking this question in a case that they have these technologies in their company
7. Do you think that detecting Mps using these technologies can reduce the cost for your company? For example, avoiding products recalls)
8. Do you think that detecting Mp e.g. using these technologies can increase your brand value? Yes, to which extent and whey? No, why not?
9. When did you buy your most recent technology and introduced that to your company? What kind of technology was that?
10. Do you have any detecting technology in your company? If yes, what kind of detecting technology?
11. What is your company's attitude toward introducing new technologies?
12. Are there any specific challenges you anticipate for your company when using these technologies for MP detection? Please specify the most important challenges.
13. Does your company have a policy about micro plastics in your products? If yes in short what is the policy (goals and how to achieve those goals)?

5. Interview consent form

Research Title: "Exploring challenges of adoption in microplastics detection technology by dairy companies"

Please tick the appropriate boxes ***Yes*** ***No***

Taking part in the study

I have read and understood the study information dated _____, or it has been read to me. □ □

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.

I understand that taking part in the study involves an audio-recorded interview, which □ □ will be transcribed and that notes will be taken during the interview. These recordings will be securely
stored on the private device of the students involved in this study. After evaluation the audio files will be deleted, and the transcripts will be anonymized.

Use of the information in the study

I understand that information I provide will be used for thesis research for the. □ □ MSc Thesis with course code BMO80424 of the Wageningen University that will be developed by the student of this thesis project.

I understand that personal information collected about me that can identify me □ □ [e.g. my name, occupation] will not be shared to any individual apart from the student

I agree that my information can be quoted in research outputs. □ □

I agree that my real name can be used for quotes. □ □

I want all my data to be anonymised. This will be done by the researcher changing my name to the title of the occupations I occupy and numbering them, if several people have the same occupation. □ □

Signatures

_____	_____	_____
Name of participant	Signature	Date

For participants unable to sign their name, mark the box instead of sign.

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.

_____	_____	_____
Researcher name	Signature	Date

6. Survey questions

Age:

Under 18

18-24

25-34

35-44

45-54

55-64

65 or older

2) Gender;

Male

Female

Prefer not to say

3) Education:

Less than high school

High school diploma or equivalent

Some college or associate degree

Bachelor's degree

Graduate or professional degree

PhD

4) Location:

Urban

Suburban

Rural

5) Have you heard about microplastics before taking this survey?

Yes

No

6) Have you heard about possibility of microplastics in dairy?

Yes

No

7) If yes, where did you gain this information from?
(Select all that apply)

Social media
University
News
Articles
Your friend
Your search outcome
Advertisements
other…

8) How familiar are you with the concept of microplastics?
familiar
Not familiar at all

9) Are you aware of microplastics' negative health effects?

Yes
No

10) From your perspective, which option can contribute more in consumer awareness about microplastic existence in food and dairy products? (Select all that apply)

Government
Schools and universities
Social Media
Food companies
EFSA, WHO, FDA
other…

11) Which sources do you trust the most for information on environmental issues like microplastics?

Government websites
Academic journals
News websites
Social media
Non-profit organizations
Environmental blogs
other…

12) What types of tools do you find most useful for learning about microplastics? (Select all that apply)
Infographics
Interactive websites
Mobile apps
Video tutorials
Webinars/seminars
Podcasts
Printed brochures or flyers
other…

13) How effective do you find each of the following strategies in raising awareness about microplastics? (Rate each from 1 to 5, where 1 is not effective and 5 is very effective)
1 2 3 4 5
Social media campaigns, Social media campaigns
Public service announcements
Celebrity endorsements
Interactive workshops
News coverage
School and community education programs

14) How often do you consume dairy products (eg, milk, cheese, yogurt)?

Several times a day
Once a day
Several times a week
Once a week
Rarely
Never

15) Are you concerned about the presence of microplastics in dairy products?

Concerned
Not concerned at all

16) Would you be willing to pay more for dairy products guaranteed to be free of microplastics?

Yes, definitely
No, I would not be willing to pay more
Not sure

17) How much more, as a percentage of the current product price, would you be willing to pay for a product without microplastics?

5%
10%
20%
30%
50%
other…

18) How important is it for you that a dairy product is labeled as microplastic-free?

Extremely important
Moderately important
Slightly important
Not important at all

19) Would you be more likely to purchase dairy products from a brand that actively promotes its efforts to reduce microplastic contamination?
Yes
No

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