

UNDERSTANDING THE PERCEPTION AND BEHAVIOUR OF ROMANIAN CONSUMERS REGARDING THE USE OF NANOTECHNOLOGY IN FOOD AND FOOD PACKAGING

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Abstract

The lack of a consistent number of studies to indicate the benefits and safety of using food nanotechnology more accurately, as well as the novelty of the field, lead to reluctance from the consumer's side. At the same time, researchers may feel discouraged by the intransigence of the consumer perception, coupled with a restrictive legislative framework. This results in a circular argument in which all actors in the food field are involved: consumer resistance to change leads to the demobilization of the scientific and academic community. This quantitative research was based on a questionnaire used to explore the acceptance of Romanian consumers (n = 359) of food products obtained or packaged using nanotechnology. In this sense, the extent to which consumers are informed about the use of nanotechnology in the agri-food sector has been determined. The research has been designed in such a way to identify the factors that influence consumers' perceptions in accepting nano-food or food packaged using nanotechnology. The aim was also to identify the demographic characteristics of consumers that would accept foodstuffs obtained or packaged using nanotechnology. The results of this research showed that consumers would more easily accept nanotechnology if it were applied to packaging rather than when it is directly applied to food. Familiarization with the term "nanotechnology" may lead to stronger opinions, either positive or negative. Food industry players could turn their attention to the presentation of concepts and benefits, as well as the risks associated with nanotechnology, to encourage consumers to form their own educated opinions. Such results may reveal an early openness from the consumers' side towards nanoengineering in general and a first step in overcoming food neophobia.

Key words: consumer studies, food innovation, nanotechnology, food packaging, nanomaterials.

INTRODUCTION

Nearly 50 years after conceptualizing the notion, nanotechnology is the science capable to revolutionize the major fields of human civilization: industry, culture, and society. Norio Taniguchi is the scientist reclaiming the paternity of the "nanotechnology" term (Taniguchi, 1974). The development of research in nanotechnology has led to the elaboration of a new class of materials called "nanomaterials". The special properties of these materials allow for improvements in lifestyle, offering alternative solutions in communication systems, medicine, and new developments in food safety and quality (Jafari & McClements, 2017).

Food contains both natural nanomaterials, such as milk casein mycelium or certain organisms found in plant or animal cells (DNA, ribosomes, enzymes, antibodies), and artificially created nanomaterials, which are deliberately added to improve food quality and safety. Some

nanoparticles are not an intrinsic part of food but may come into contact with it due to their inclusion in food packaging or in nanosensors.

Nanomaterials for the food industry are used in food processing as food additives, in the manufacture of packaging, in the development of nutraceuticals and increasing nutrient bioavailability, and in the production of sensors especially designed to detect toxins, pathogens or pesticides (Dasgupta et al., 2015; Marin et al., 2017; He et al. 2019).

Despite the advantages proposed using nanotechnology in the food industry, a noteworthy aspect that can make it difficult to market foods that present novelties and innovations is related to consumer behaviour and perception. In this sense, consumer study and education become essential for the survival of newly introduced food products. Notable research has shown the importance of taking the "consumer" factor into account when developing innovative products (Chen et al., 2020; Lakomaa et al., 2021).

Given the challenge to place genetically modified organisms (GMOs) on the market, consumer acceptance of modern technologies cannot be taken for granted. While consumers consider cost, safety, and quality in purchasing decisions, they are also emotional beings and have their own considerations regarding production practices and ethics, factors that play an increasingly significant role in such decisions (Dagevos, 2013).

As with any emerging technology, there are still considerable knowledge gaps (Erdem, 2018). Existing uncertainties have led to a significant increase in consumer concerns, especially regarding the effectiveness of nanotechnology, long-term side effects and the real ability to ensure safety (Gupta et al., 2017).

Over time, consumer perception regarding nanotechnology, in general, has been extensively studied (Siegrist et al., 2007; Capon et al., 2015; Giles et al., 2015). The available research shows that attitudes towards nanotechnology are particularly positive in many application areas. Consumers expect the benefits of nanotechnology to show in the pharmaceutical and medical fields and for technological development, in contrast to the agri-food sector. Food-related applications tend to be a public concern compared to other applications, with consumers being reluctant to buy food resulting from nanotechnology. Priest & Greenhalgh (2011) had similar conclusions - the participants in their study consider that nanotechnology brings benefits for medicine, but for the agri-food field the benefits were not as obvious.

Our study aims to explore the current perception of Romanian consumers regarding the use of nanotechnology. To our knowledge, no other similar research has been conducted in this sense.

MATERIALS AND METHODS

There are three distinct paradigms in research that are often used to guide research methodology and analysis: positivism, interpretivism, and realism. The *research philosophy* adopted in this study is "Positivism". Positivism is a philosophy suitable for natural sciences, in which the researcher is objective, independent of the study, and usually presents the results of the analysis in

a quantifiable manner. Researchers who choose positivism use existing theory to develop and assess hypotheses, to confirm or invalidate them, or to suggest directions for further research (Candy, 1989; Kivunja & Kuyini, 2017).

As the scientific literature on consumer behavior and perception on the use of nanotechnology for the food industry is limited and outdated (the most relevant papers were written in 2005-2006), we wanted to examine the consumer perception in 2021. The uniqueness of the study also consists of addressing the Romanian consumers.

For this study, the "deductive" *approach* has been used. The deductive research approach is closely aligned with quantitative analysis, and it is based on testing one or more theories to examine "cause and effect", to anticipate results, to separate facts from opinions, and to control research in such a way to establish relationships between data sets (Robson & McCartan, 2015). In this approach, the theory comes from the analysed scientific literature.

For operational purposes, to make the collection more efficient, the use of a single research method was chosen, namely the survey method. It is interesting to note that although Ahmed and Sil (Ahmed & Sil, 2012) recognize the benefits of multi-method research, they suggest that validating data from often different methods is difficult, prone to errors and variations in interpretations.

The *instrument* used to collect the data is a *questionnaire*. The online software "SurveyMonkey" was used to manage the surveys. The survey consists of 14 questions. The first and second questions concern the identification of the respondents - they are designed to obtain general information about their sex and age. The following two questions were asked to investigate whether respondents had heard of the term "nanotechnology" and what they associate it with. Next, it has been introduced a section that summarizes what nanotechnology is and some of its possible applications. After reading this part, respondents are asked a set of questions about their knowledge of using nanotechnology for food. They are also asked to indicate what are the sources they consider to be reliable if they want to inform themselves about nanotechnology.

Respondents address statements related to their need for information on the use of nanotechnology for food, in the form of appropriate product labelling. Questions 8 to 11 were designed to provide information on consumer perceptions. These refer to the benefits and risks associated by consumers with certain applications of food nanotechnology. Questions 12-14 are demographic, with respondents providing information about the last form of education completed, who is the person in charge of shopping, and monthly income (expressed in Romanian currency – LEI) for the entire household.

In addition to "SurveyMonkey", "Microsoft Excel" was used for its PivotTable function.

RESULTS AND DISCUSSIONS

The survey was designed to assess the level of consumer acceptance of the use of nanotechnology. 359 respondents participated to the study – 120 males (33.43%) and 239 females (66.57%). This kind of information is needed to make future correlations about the type of consumers who might be open to nanotechnology in food production and packaging, as well as to describe those who would be reluctant to the use of this technology. The gender fragmentation was correlated as closely as possible with the statistical data resulting from the report of the National Institute of Statistics and Economic Studies (INSSE), stating that Romania's population consists of 51.1% women and 48.9% men. However, it was also taken into account that women are more willing to participate in market research than men. Smith (2008) observed a trend in which participants' gender influences their desire to take part in questionnaires, especially when administered in the traditional (paper) way; the influence is slightly lower when the survey is electronic. Regarding the age distribution of respondents (Figure 1), most are between 30-39 years old (28.69% or 103 respondents). Respondents aged between 21 and 29 is the second most represented category (24.79% or 89 respondents). The lowest percentage belongs to the participants who fall into the group of 60 years old and more, 8.64% (31 people). The lowest age to participate in the survey was 18 years old.

Those who did not meet this requirement were automatically excluded from the study.

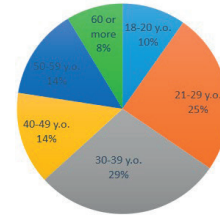


Figure 1. Distribution of sample population by age

Figure 2 depicts the results obtained after asking the participants whether they are familiar with the term "nanotechnology". It can be observed that more than two-thirds of the respondents state that they are familiar with the term "nanotechnology". Questions in future sections will check this statement and try to highlight whether the participants in the study have relevant knowledge about this technology.

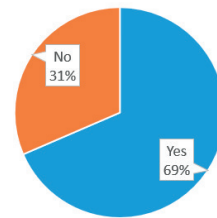


Figure 2. Answers regarding the knowledge of the term "nanotechnology"

Brown & Kuzma conducted a similar study in 2013. They concluded that the general population has little or limited knowledge about nanotechnology, which influences the decision to buy the by-products. The lack of knowledge as an impediment in accepting a new technology was highlighted even more recently, in 2020, by van Giesen et al. - they explained that it is difficult for consumers to form an opinion when they are not sufficiently informed about a topic. When trying to explore respondents' knowledge regarding nanotechnology they were asked in an open-ended question to note what they associated the term with. Most study participants referred to the technology in question using terms in the lexical field of the words "small," "future," "robotics," "scale," "novelty," "evolution," "movies," or "microchips".

For further understanding of the respondents' knowledge about nanotechnology, participants were asked to indicate whether they "agreed", "disagreed" or "did not know" on two statements. One refers to a possible similar behaviour of nanomaterials when used in larger scales and the other one states that nanotechnology involves materials that are not visible to the human eye.

Table 1 shows 38.72% of respondents believe that nanomaterials behave similarly to larger scales, but 28.69% disagreed with this statement. One-third of the participants did not know how to answer this question. Regarding the visible spectrum of nanomaterials, most of the respondents agreed that they are not visible to the naked eye.

The same set of statements also sought to deliver information on consumers' perceptions regarding the need to regulate the use of nanotechnology in food or food packaging. The general will is that regulators should have strict control over food nanotechnology. However, a difference of one per cent (5 respondents) can be observed between the nanotechnology used for food packaging and nanotechnology used for food production. Thus, 77.37% of the participants agree that the use of nanotechnology for food packaging should be strictly regulated, and 78.77% of respondents believe that when nanotechnology is applied to food, it is necessary to have strict legislative control. These results are in line with the scientific literature that mentions consumers may be more open to nanotechnology when it manifests itself on the outside of food (Giles et al., 2015; Zhou & Hu, 2018).

Consumers, however, although reluctant to consume food obtained or packaged using nanotechnology, agree (81.34%) with the statement that nanotechnology could be a possible solution to reduce the consumption of the planet's resources. This is an important finding that may indicate a future openness and acceptance of nanotechnology if it manifests its concrete benefits. The fact that so many respondents agree with this statement also underscores that human nature is not only based on cognition but also on affectivity as well as the care for future generations.

Many factors determine how consumers might respond to the use of new nanotechnologies. These include, but are not limited to, media coverage, past individual experiences with other innovative technologies, general attitudes, beliefs, knowledge, and preferences. Among these factors, the level of trust a person has in the food system (producers, processors, traders) and in the regulatory process that oversees it is also a critical issue. In the case of the introduction of new technologies, trust is a fundamental pillar (Roosen et al., 2015; Gupta et al., 2017). This perspective is especially true when consumer knowledge and experience about new technologies are limited, and consumers have the support of expert advice. The experts represent the mechanism that reduces the complexity when consumers judge the risks and benefits of new technologies (Gupta et al., 2017; Siegrist & Cvetkovich, 2020). On the other hand, a lack of trust in institutions could hinder the adoption of modern technologies and generate resistance to new policies (Hobbs & Goddard, 2015).

Table 1. Set of questions addressed to determine the knowledge of consumers regarding nanotechnology

Statement	Answers			Total
	Agree	Disagree	I do not know	
Nanomaterials have similar behaviour to the materials on larger scales	139 (38,72%)	103 (28,69%)	117 (32,59%)	359 (100%)
Nanotechnology implies materials not visible to the human eye	323 (89,97%)	20 (5,57%)	16 (4,46%)	359 (100%)
The use of nanotechnology for food production should be strictly regulated	282 (78,7%)	14 (3,91%)	62 (17,32%)	358 (100%)
The use of nanotechnology for food packaging should be strictly regulated	277 (77,37%)	22 (6,15%)	59 (16,48%)	358 (100%)
Nanotechnology may help in reducing the consumption of the Planet's resources	292 (81,34%)	14 (3,90%)	53 (14,76%)	359 (100%)

As education is one of the main contributors that could lead to changes in consumer perception and behaviour, it is relevant to identify the main actors in the food field that are trustworthy, as an information source for interested consumers. Because nanotechnology is a recent technology and the public has very little related knowledge, it is therefore important to gain confidence and

be able to trust those institutions responsible for the development and regulation of the food in question.

Table 2 shows that participants have the greatest confidence when it comes to information about nanotechnology coming from scientists (from universities, research institutes). The National Veterinary Sanitary and Food Safety Authority (ANSVSA) also enjoys a high degree of trust. The next most trusted information source for consumers is the Consumer Associations. These results are like those obtained by Erdem in 2018 (Erdem, 2018). His study on British consumers showed that they have the greatest confidence in nanotechnology in government institutions, researchers, and consumer associations - in that order.

Respondents participating in our study are reluctant to receive information from food industry actors (producers, distributors, traders). British consumers have a similar perspective (Erdem, 2018). However, other studies show that industry representatives are willing to work with public institutions and consumers to assure a smooth functioning of the food chain (Baicu, 2016). The Romanian consumers show little trust in the information they encounter on the Internet, social media, and mass media. Less than 15% of the respondents trust or rely heavily on these possible sources of information.

Considering the importance of food for human beings, education about the technical and rational aspects of new food technologies may not be sufficient to determine consumer acceptance. Price, good taste and comfort are some of the proposed key considerations in today's market. For a third of the European consumers, moral and ethical issues are important in decision-making about the food they eat. Rollin et al. (2011) point out that the Europeans are likely to get over the risks associated with nanotechnology, if they perceive the benefits of it but also if they conclude it is a morally acceptable technology.

The same authors indicate the need for clear labelling of food, as it increases the consumers' perception of self-control (Rollin et al., 2011).

Table 3 supports the above statements and shows that Romanian consumers in 2021 want to be informed about the use of nanotechnology

in the food they could consume. Thus, in the case of the statement that Consumers are sufficiently informed about the regulation of nanomaterials, over 70% of them expressed their disagreement or total disagreement.

Table 2. Set of questions addressed to determine the level of trust that consumers would grant to different food field stakeholders regarding the information on nanotechnology they would issue

Stakeholder	Answers					Total
	Very reliable	Reliable	Neutral	Somewhat reliable	Not reliable	
The National Veterinary Sanitary and Food Safety Authority	55 (15,36%)	133 (37,15%)	95 (26,54%)	54 (15,08%)	21 (5,98%)	358 (100%)
Consumer Associations	39 (10,86%)	131 (36,49%)	103 (28,69%)	62 (17,27%)	24 (6,69%)	359 (100%)
Food industry (producers, distributors, traders)	13 (3,63%)	68 (18,99%)	114 (31,84%)	82 (22,91%)	81 (22,63%)	358 (100%)
Scientists (research institutions, universities)	132 (36,87%)	150 (41,90%)	42 (11,73%)	28 (7,82%)	6 (1,68%)	358 (100%)
Mass-media	5 (1,39%)	36 (10,03%)	78 (21,73%)	101 (28,13%)	139 (38,72%)	358 (100%)
Internet, social media	6 (1,68%)	37 (10,34%)	96 (26,82%)	102 (28,49%)	117 (32,68%)	358 (100%)

Concerning labelling, the respondents show their need to be informed if the food was produced using nanotechnology. Slightly lower percentages are recorded when study participants were asked to express their views on the need for a label stating that the food packaging contains nanomaterials.

This difference may suggest a greater openness of the consumers when nanotechnology is used in packaging rather than when it is used in food. This result is also in line with previous studies showing that there may be a greater receptivity towards nanotechnology when applied externally.

The need to inform consumers is also emphasized by the responses regarding a food label to indicate the use of nanotechnology despite having stricter legislation for manufacturers. As in the previous set of statements, consumers expressed their agreement (49.16%) or total agreement (37.43%) to keep a nanotechnology symbol on the label if the food contains nanomaterials, but the percentages are lower (agreement - 43.18%; total agreement - 34.82%) for the use of the symbol when the food packaging contains nanomaterials.

Table 3. Set of statements with regards to the need of the consumers to be informed about nanotechnology

Statement	Answers					Total
	Totally agree	Agree	Neutral	Disagree	Totally disagree	
The consumers are sufficiently about addressed about regulating food nanotechnology	12 (3,35%)	13 (3,63%)	73 (20,39%)	167 (45,81%)	96 (26,82%)	358 (100%)
When nanotechnology is applied to food, no label is needed to indicate this	8 (2,23%)	19 (5,31%)	42 (11,73%)	148 (41,34%)	141 (39,39%)	358 (100%)
When nanotechnology is applied to food packaging, no label is needed to indicate this	13 (3,63%)	37 (10,31%)	48 (13,37%)	149 (41,50%)	112 (31,20%)	259 (100%)
If the relevant legislation is stricter, no label is needed to indicate the use of nanotechnology in food production	134 (37,43%)	176 (49,16%)	32 (8,94%)	10 (2,79%)	6 (1,68%)	358 (100%)
If the relevant legislation is stricter, no label is needed to indicate the use of nanotechnology in food packaging	125 (34,82%)	155 (43,18%)	34 (9,47%)	34 (9,47%)	11 (3,06%)	359 (100%)

Another step taken to understand consumers' perceptions of the risks and benefits associated with nanotechnology applications in food production, consisted of presenting the respondents a series of possible applications of nanotechnology in food production. The research participants were asked to specify whether any of these applications would lead them to purchase the product. Table 4 shows that if nanomaterials reduced the chances of a food product to make them sick, the participants to the study would be interested in such a food benefit. Also, favourable answers were given to the options in which nanotechnology would lead to more nutritious products, or if the products would keep their freshness longer. The use of nanomaterials in food packaging could also be a factor that would convince consumers if the application would determine a longer shelf life. The "I would not buy" option is the least popular answer.

Table 4. Determining factors to buy food containing nanomaterials

Nanotechnology applications that would determine the Romanian Consumers to buy food products containing nanomaterials -statements-	Answers	
	%	Count
Nanomaterials would lower the chances that a food product would make me sick	71,59	257
Food becomes more nutritious	40,39	145
Food is fresh for longer	36,49	131
Nanotechnology would indicate if the food contained allergens	16,71	60
The food packaging has unique features	20,06	72
If the nanomaterials are used in the food packaging and this would lead to a longer shelf-life of the food product	28,69	103
I would not buy	8,08	29

The results of our study are consistent with those presented in the current scientific literature, pointing out that when consumers perceive potential benefits, there may be more interested and confident about modern technologies.

Figure 3 shows that more than half (54%) of the research participants would trust a large, well-known company, if they were to buy nanofoods. On the other side, a boutique shop specialized in commercializing food with unique features would only attract 29% of the respondents willing to buy nano-based food.

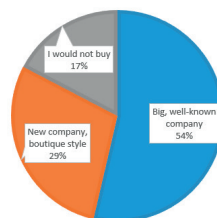


Figure 3. Consumer preferences regarding the type of company where they would buy food obtained or packaged with the use of nanotechnology

This question was addressed in order to understand what kind of companies would be successful, in an initial phase, in the production and marketing of nano food products, so what kind of company could open such a market. The results are similar to those obtained in previous research, which aimed to study the possible benefits of changes in European legislation governing novel foods, namely the simplification of procedures to be followed by companies to place such a product on the market (Baicu & Popa, 2016). Current research has also shown that, in theory, small and medium-sized food companies would have more opportunities to enter the market under the new regulation, as the time and money invested in the authorization procedure would be reduced. However, after the empirical analysis, the effect of the new procedures is different in the opinion of the consumer. Consumers would be suspicious of nano foods and would prefer to buy them from large, well-known companies that they consider reliable. It

is appropriate to emphasize the consumer's willingness to buy traditional food from smaller companies, boutique or local companies, given that food manufactured on a larger scale will not provide the same specific quality. However, as far as nano-foods are concerned, consumers would still be cautious and believe that larger companies would be better suited to this situation. Therefore, small businesses will face barriers when trying to enter the market with foodstuffs obtained or packaged using nanotechnology. Small and medium-sized enterprises will have to wait for another stage, when consumers will gather more information and confidence about nanotechnology food after buying such products from large companies.

Figure 4 depicts the possible consumer concerns that would prevent them from buying food that uses nanotechnology. The most notable issue that would prevent consumers from buying nano-foods is that scientific studies have not gathered enough data to draw conclusions about the long-term effects of nanomaterials on human health. This factor is particularly important, as it shows the willingness of respondents to buy such food if the research in the field were to advance and the potential risks would be presented by the scientific community. Study participants point to the lack of solid data on risks and no other reasons, such as ethics. Another popular response came from respondents' awareness that they were not well enough informed about nanotechnology. Most study participants realize the need for education. Therefore, a risk communication system about nanotechnology could support this part of the population. At the same time, communication channels should be established and implemented to ensure continuing education on nanotechnologies and newly developed products. According to this research, consumers are willing to receive information from researchers, food safety authorities, but also from consumer associations. Therefore, the communication channels could initially include these three actors, and

later are the industry representatives that could take part in the communication process. Another proposal would be to prepare educational programs as a first step, and then to include consumers in consultations and decision-making discussions.

From the answers provided by the survey participants, we also point out that part of the consumers still prefers traditional foods instead of innovative ones, but this group of respondents is not the majority. The possible high price of food using nanotechnology would also not be the first barrier for consumers.

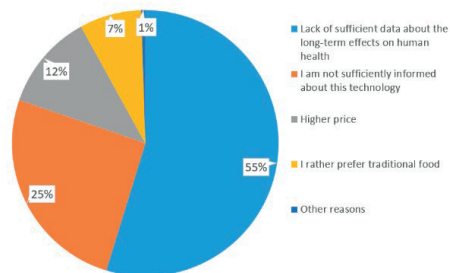


Figure 4. Factors that would determine a reserved behaviour in buying nanotechnology-based food

Table 5 shows the answers of the participants regarding a set of statements addressed to assess the perceived naturalness of the use of nanotechnology. The respondents were expected to either agree or disagree with the proposed statements.

The trend shows that consumers are relatively open to the use of food nanotechnology. Like the previous results of this study, a lower level of reticence is shown regarding the use of nanotechnology for food packaging rather than for food production. A generally positive attitude is expressed for encouraging research for the development of nanotechnology both for food and for food packaging. A higher number of respondents encourages the use of nanotechnology for food packaging (agree – 43.45%; totally agree – 22.84%) than for food production (agree – 14.76%; totally agree – 38.16%).

Table 5. Perceived natural nature of the use of nanotechnologies in the food industry

Statement	Answers						Total
	Totally agree	Agree	Neutral	Disagree	Totally disagree	I do not know	
I would buy food carrying a label that it was produced using nanotechnology	53 (14,76%)	149 (41,50%)	77 (21,45%)	22 (6,13%)	30 (8,36%)	28 (7,80%)	359 (100%)
I would buy food carrying a label that the packaging was obtained using nanotechnology	80 (22,28%)	171 (47,63%)	59 (16,43%)	11 (3,06%)	16 (4,46%)	22 (6,15%)	359 (100%)
I would eat food carrying a label that it was produced using nanotechnology	55 (15,32%)	133 (37,06%)	87 (24,23%)	21 (5,85%)	30 (8,36%)	33 (9,19%)	359 (100%)
I would eat food carrying a label that the packaging was obtained using nanotechnology	79 (22,01%)	163 (45,40%)	69 (19,22%)	12 (3,34%)	15 (4,18%)	21 (5,85%)	359 (100%)
I would offer food obtained using nanotechnology to my family	51 (14,21%)	121 (33,70%)	93 (25,91%)	27 (7,52%)	33 (9,19%)	34 (9,47%)	359 (100%)
I would offer food packaged with nanomaterials to my family	72 (20,06%)	146 (40,67%)	79 (22,01%)	14 (3,90%)	18 (5,01%)	30 (8,36%)	359 (100%)
Nanotechnology for food production is acceptable	53 (14,76%)	137 (38,16%)	93 (25,91%)	15 (4,18%)	21 (5,85%)	40 (11,14%)	359 (100%)
Nanotechnology un food packaging is acceptable	82 (22,84%)	156 (43,45%)	66 (18,38%)	9 (2,51%)	12 (3,34%)	34 (9,47%)	359 (100%)
The use of nanotechnology for food production should be encouraged	71 (19,78%)	132 (36,77%)	82 (22,84%)	12 (3,34%)	23 (6,41%)	39 (10,89%)	359 (100%)
The use of nanotechnology for food packaging should be encouraged	93 (25,91%)	149 (41,50%)	60 (16,71%)	10 (2,79%)	14 (3,90%)	33 (9,19%)	359 (100%)
The use of nanotechnology in the food sector may contribute to reducing world hunger	81 (22,56%)	109 (30,36%)	78 (21,73%)	16 (4,46%)	19 (5,29%)	56 (15,60%)	359 (100%)

A control question was included. It refers to the consumers perception regarding the use of nanotechnology in the food sector as a possible factor to reduce world hunger. The answers are comparable to the ones received and presented in an earlier set of questions (Table 1).

The last three questions of the survey are demographic and useful to correlate and determine which type of consumer might be more open to food nanotechnology.

From Figure 5 it is observed that most (36%) of the respondents hold a bachelor's degree. The second most representative group (29%) is that of master's degree graduates. 23% of the participants only finished high school. 7% of the respondents hold a doctorate degree.

The graph in Figure 6 shows that 40% of respondents are the only ones responsible for shopping in their households, while more than half (54%) of them share this task with someone else.

Regarding respondents' income, most (24%) are part of the households where they earn a total of over 8500 LEI per month. The second most represented category (16%) is that of those living in households where the total income is between 6501-8500 LEI per month, almost equal to those with incomes between 2500-3500 LEI (15%) per month. The complete results are shown in Figure 7.

One of the goals of this research was to describe the consumer open to the applications of nanotechnology in the food field. As a results, several correlations of the survey findings were made.

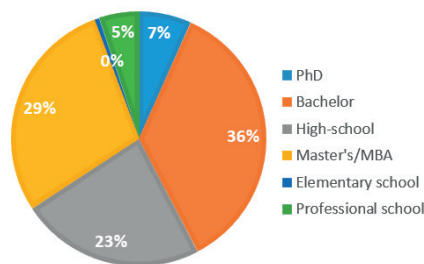


Figure 5. Completed level of education by the research participants

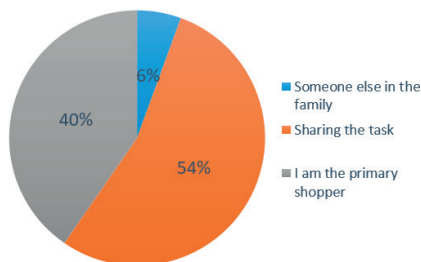


Figure 6. Who is doing the groceries in the participants' household

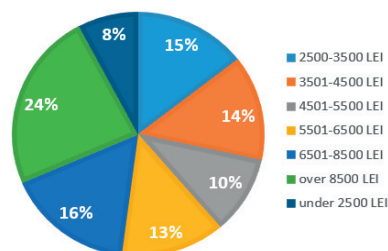


Figure 7. Total average income in the research participants' households

Table 6. Influence of the age factor on the familiarity with the nanotechnology term

Are you familiar with the term of „nanotechnology“?	Age												
	18-20 y.o.	% of total per age group	21-29 y.o.	% of total per age group	30-39 y.o.	% of total per age group	40-49 y.o.	% of total per age group	50-59 y.o.	% of total per age group	60 y.o. or more	% of total per age group	Total answers
Yes	22	63%	53	59%	78	76%	33	65%	37	74%	23	74%	246
No	13	37%	36	41%	25	24%	18	35%	13	26%	8	26%	113
Total respondents	35	100%	89	100%	103	100%	51	100%	50	100%	31	100%	359

Correlation between age and the familiarity with the “nanotechnology” term. This correlation helps in performing an analysis of how age plays a role regarding the familiarity with the term “nanotechnology”. The results of this correlation are presented in Table 6. It can be observed that, compared to the number of participants in each age category, the highest percentages of respondents who declared they were familiar with the term are recorded for the groups 30-39 years old, 50-59 years old and over 60 years old. The least familiar with the “nanotechnology” term are young adults aged 21-29 - 41% of them admit they do not know the term.

Gender influence on the intention to consume food obtained or packaged using nanotechnology. Although the general intention of the research participants is positive in terms of the consumption of food products to which nanotechnology has been applied, differences in perception can be observed depending on how the technology is applied (on the food or on the packaging), but also depending on the sex of the respondents. Table 7 shows that shy over half of the women surveyed agree to eat foods whose label states that they were produced using nanotechnology (40.58% - agreement and 12.55% - total agreement). Similar answers were given by men (30% - agreement and 20.83% - total agreement). However, the fragmentation of opinions is more pronounced among men, who also generate many negative responses (35% total agreement or disagreement), compared to women who chose to be neutral.

On the other hand, when the use of nanotechnology is applied to the food packaging, men are much more open than women (Table 8). If among women the percentages remain similar to those for food products obtained using nanotechnology, among men there are more positive answers and fewer negative opinions:

41.66% - agreement, 33.33% total agreement and only slightly more than 10% disagreement (5.83% disagreement; 5% total disagreement). These results indicate a need for possible nanotechnology education or popularization programs depending on the audience.

Table 7. Intention to eat food obtained using nanotechnology depending on the gender of the respondents

I would eat food carrying a label that it was produced using nanotechnology	Number of answers relative to the gender of the participants				
	Male	% of total (m)	Female	% of total (f)	Total
Agree	36	30%	97	40.58%	133
Totally agree	25	20.83%	30	12.55%	55
Disagree	12	10%	9	3.76%	21
Totally disagree	21	17.5%	9	3.76%	30
Neutral	21	17.5%	66	27.61%	87
I do not know	5	4.16%	28	11.71%	33
Total	120	100%	239	100%	359

Table 8. Intention to eat food packaged using nanotechnology depending on the gender of the respondents

I would eat food carrying a label that the packaging was obtained using nanotechnology	Number of answers relative to the gender of the participants				
	Male	% of total (m)	Female	% of total (f)	Total
Agree	50	41.66%	113	47.28%	163
Totally agree	40	33.33%	39	16.31%	79
Disagree	7	5.83%	5	2.09%	12
Totally disagree	6	5%	9	3.76%	15
Neutral	16	13.33%	53	22.17%	69
I do not know	1	0.83%	20	8.36%	21
Total	120	100%	239	100%	359

According to the responses received from the respondents, the women who did not express their agreement had neutral answers regardless the application of nanotechnology. A deeper familiarity with the concept could lead them to form other opinions. As men are more receptive to the applications of nanotechnology in food packaging, it is likely that a rigorous presentation of the risks and benefits of using nanotechnology in food production could lead them to consider such an application as well.

Correlation between education level and the willingness to eat food obtained using nanotechnology. The higher the education

level of the respondents, the greater their openness to eat of food products obtained or packaged using nanotechnology. Tables 9 and 10 display the results obtained after correlating the level of studies declared by

the survey participants in relation to the way they would behave regarding the consumption of food products obtained using nanotechnology or packaged using nanotechnology.

Table 9. Influence of education level on the willingness to eat food obtained using nanotechnology

I would eat food carrying a label that it was produced using nanotechnology	Number of answers relative to the education level of the respondents												
	Answers	PhD	% of total	Bachelor	% of total	High school	% of total	master/MBA	% of total	Elementary school	% of total	Professional school	% of total
Agree	14	58.33%	45	35.15%	28	33.33%	40	38.83%	-	-	6	33.33%	133
Totally agree	2	8.33%	21	16.4%	11	13.09%	17	16.5%	-	-	4	22.22%	55
Disagree	-	-	9	7.03%	6	7.14%	3	2.91%	1	50%	2	11.11%	21
Totally disagree	2	8.33%	8	6.25%	13	15.47%	4	3.88%	-	-	3	16.66%	30
Neutral	4	16.66%	33	25.78%	17	20.23%	31	30.09%	-	-	2	11.11%	87
I do not know	2	8.33%	12	9.37%	9	10.71%	8	7.76%	1	50%	1	5.55%	33
Total	24	100%	128	100%	84	100%	103	100%	2	100%	18	100%	359

Table 10. Influence of education level on the willingness to eat food packaged using nanotechnology

I would eat food carrying a label that the packaging was obtained using nanotechnology	Number of answers relative to the education level of the respondents												
	Answers	PhD	% of total	Bachelor	% of total	High school	% of total	master/MBA	% of total	Elementary school	% of total	Professional school	% of total
Agree	16	66.66%	56	43.75%	38	45.23%	47	45.63%	-	-	6	33.33%	163
Totally agree	2	8.33%	28	21.87%	17	20.23%	26	25.24%	-	-	6	33.33%	79
Disagree	-	-	4	3.12%	4	4.76%	1	0.97%	1	50%	2	11.11%	12
Totally disagree	1	4.16%	4	3.13%	5	5.95%	4	3.88%	-	-	1	5.55%	15
Neutral	3	12.5%	29	22.65%	15	17.87%	20	19.41%	-	-	2	11.11%	69
I do not know	2	8.33%	7	5.46%	5	5.95%	5	4.85%	1	50%	1	5.55%	21
Total	24	100%	128	100%	84	100%	103	100%	2	100%	18	100%	359

58.33% of the participants holding a PhD degree expressed their agreement on the possibility to consume food products obtained using nanotechnology, while 8.33% expressed a total agreement in this regard. The doctorate diploma holders form the smallest group of participants that stand neutral on this issue. Among the respondents with a master's degree or MBA diploma, 38.83% agree and 16.5% fully agree to consume nanofoods. 35.15% of the respondents who have completed a bachelor's degree agree to consume food obtained using nanotechnology, and 16.4% express their total agreement. Generally positive answers are also provided by high school and post-high school graduates. Thus, 33.33% of those who obtained a post-secondary education diploma would consume products obtained with the help of nanotechnology, and 22.22% expressed their total agreement in this regard. The trend is similar in terms of consumer behaviour towards using nanomaterials for

food packaging: the more advanced the level of education of the survey participants, the stronger their intention to consume the mentioned products. However, it is interesting to note that for all categories of respondents (regardless of the form of education completed), the total number of positive responses (agreement or total agreement) is about 11.2% higher in this case, which shows that among the respondents, the use of nanotechnology for food packaging is easier to accept rather than when nanotechnology is used in food production. The results are similar to those reported in the scientific literature (McCarron, 2016; Kapteina, 2016; Smith et al., 2008) also show that respondents with higher levels of education were “significantly more likely to have heard about nanotechnology” and those with higher education are “more likely to perceive that the benefits outweigh the risks, while those with a lower level of education perceive that the risks outweigh the benefits”.

Correlation between the income category of the household to which the respondent belongs on the intention to consume food obtained or packaged nanotechnology.

The intention of the respondents to eat food products obtained or packaged using nanotechnology was also correlated with the monthly average income of their household. These correlations are depicted in Table 11 (for

products obtained using nanotechnology) and in Table 12 (for products packaged using nanotechnology).

After analysing the obtained data, it can be observed that the monthly income of the household does not play a significant role, the scores obtained being similar to each other, regardless of the application of nanotechnology.

Table 11. The influence of the income category of the household to which the respondent belongs on the intention to consume food obtained with the use of nanotechnology

I would eat food carrying a label that it was produced using nanotechnology	Number of answers relative to the income group of the respondents												Total answers		
	2500-3500 LEI	% of total	3501-4500 LEI	% of total	4501-5500 LEI	% of total	5501-6500 LEI	% of total	6501-8500 LEI	% of total	Over 8500 LEI	% of total		Under 2500 LEI	% of total
Agree	21	40.38%	18	36%	12	32.43%	23	47.91%	18	30.5%	30	35.29%	11	39.28%	133
Totally agree	7	13.46%	6	12%	6	16.21%	5	13.51%	11	18.6%	18	21.17%	2	7.14%	55
Disagree	5	9.61%	2	4%	1	2.7%	2	4.16%	5	8.47%	5	5.88%	1	3.57%	21
Totally disagree	4	7.69%	4	8%	2	5.4%	1	2.08%	10	16.9%	7	8.23%	2	7.14%	30
Neutral	10	19.23%	17	34%	12	32.43%	14	29.16%	12	20.3%	14	16.47%	8	28.57%	87
I do not know	5	9.61%	3	6%	4	10.81%	3	6.25%	3	5.08%	11	12.94%	4	14.28%	33
Total	52	100%	50	100%	37	100%	48	100%	59	100%	85	100%	28	100%	359

Table 12. The influence of the income category of the household to which the respondent belongs on the intention to consume food packaged with the use of nanotechnology

I would eat food carrying a label that the packaging was obtained using nanotechnology	Number of answers relative to the income group of the respondents												Total answers		
	2500-3500 LEI	% of total	3501-4500 LEI	% of total	4501-5500 LEI	% of total	5501-6500 LEI	% of total	6501-8500 LEI	% of total	Over 8500 LEI	% of total		Under 2500 LEI	% of total
Agree	23	44.23%	22	44%	17	45.94%	25	52.08%	27	45.76%	37	43.59%	12	42.85%	163
Totally agree	10	19.23%	9	18%	6	16.21%	11	22.91%	20	33.89%	20	23.52%	3	10.71%	79
Disagree	5	9.61%	2	4%	1	2.7%	-	-	1	1.69%	1	1.17%	2	7.14%	12
Totally disagree	3	5.76%	1	2%	2	5.4%	1	2.08%	2	3.38%	5	5.88%	1	3.57%	15
Neutral	7	13.46%	13	26%	8	21.62%	11	22.91%	8	13.55%	15	17.64%	7	25%	69
I do not know	4	7.69%	3	6%	3	8.1%	-	-	1	1.69%	7	8.23%	3	10.71%	21
Total	52	100%	50	100%	37	100%	48	100%	59	100%	85	100%	28	100%	359

However, respondents with higher income tend to be more open to consuming food obtained or packaged using nanotechnology. Thus, in the case of using nanotechnology at the food product level, the most receptive consumers are those who come from households where the monthly income is over 8500 RON. The results obtained regarding the consumption of packaged products using nanotechnology, did not generate a uniform model that would lead to conclusions about a possible correlation between receptivity or reluctance towards nano-packaging and monthly revenues. In their research, Yue et al. (2015) also observed that individuals with higher incomes tend to have positive attitudes towards nano-foods as well as towards genetically modified

organisms. The same finding was made by Kapteina in 2016, that analysed how the demographic factors influence consumer behaviour regarding the use of nanotechnology in the food sector. Moreover, Tran et al. (2019) reported that the higher-income participants in their study are willing to pay more for food packaging (involving nanotechnology) if they lead to a safer food product, but also for food (beef, in that case) which would become safer as a result of the use of nanotechnology (Tran et al., 2019). Wang et al. (2019) correlated the higher incomes of the participants in their study with the desire to buy premium products and products containing ingredients that come from organic farming. There is a trend in the scientific literature that consumers with high

levels of education and high incomes are more willing to try to eat special and new foods. This type of consumer demonstrates a greater ability to weigh the risks and benefits the new technologies bring to the food industry.

Correlation between the familiarity with the term “nanotechnology” and intention to eat food obtained or packaged using nanotechnology. Table 13 and Table 14 display the results of the correlation between the participants' answers to the question “Are you familiar with the term *nanotechnology*?” and their intention to consume food obtained or packaged using nanotechnology. We wanted to validate or invalidate the hypothesis that consumers who are familiar with the term nanotechnology would be more receptive and open to consuming foods that have been of this technology.

More than half of the consumers participating in the study expressed their agreement or total agreement on the consumption of food products obtained using nanotechnology (Table 13). The fact that the respondents were familiar with the term nanotechnology led to several answers of total agreement: 18.69% when the term was known and 7.96% when the term was unknown to the participants. The answers suggesting resistance to nanofood consumption were also influenced by the familiarity with the term “nanotechnology” - of those familiar, 18.28% expressed disagreement or total disagreement with the consumption of nano foods, while respondents unfamiliar with the term offered a percentage slightly higher than 5% in terms of disagreement or total disagreement with the consumption of such products.

Similar results have been obtained regarding the intention to consume foods whose label states that the packaging was made using nanotechnology. However, the percentages of individuals open to such an application are higher than in the case of nano-foods, whether or not the term nanotechnology is known to them. 72.76% of respondents who are familiar with the term *nanotechnology* are more receptive to nano-packaging, compared to 55.74% who would consume nano-packaged food, although they do not know the term. It is also noteworthy that 30% of people who

declare they were unfamiliar with the term nanotechnology preferred to remain neutral when asked if they would consume such packaged foods.

Table 13. Familiarity with the *nanotechnology* term and the willingness to eat nanotechnology-based food

I would eat food carrying a label that it was produced using nanotechnology	Results relative to the respondents' answers to the question “Are you familiar with the term <i>nanotechnology</i> ?”				
	Answers	Yes	% of total	No	% of total
Agree	91	36.99%	42	37.16%	133
Totally agree	46	18.69%	9	7.96%	55
Disagree	19	7.72%	2	1.76%	21
Totally disagree	26	10.56%	4	3.53%	30
Neutral	45	18.29%	42	37.16%	87
I do not know	19	7.72%	14	12.38%	33
Total	246	100%	113	100%	359

Table 14. Familiarity with the nanotechnology term and the willingness to eat food packed with the use of nanotechnology

I would eat food carrying a label that the packaging was obtained using nanotechnology	Results relative to the respondents' answers to the question “Are you familiar with the term <i>nanotechnology</i> ?”				
	Answers	Yes	% of total	No	% of total
Agree	111	45.12%	52	46.01%	163
Totally agree	68	27.64%	11	9.73%	79
Disagree	10	4.06%	2	1.76%	12
Totally disagree	12	4.87%	3	2.65%	15
Neutral	35	14.22%	34	30.08%	69
I do not know	10	4.06%	11	9.76%	21
Total	246	100%	113	100%	359

The data obtained from this correlation indicates that familiarization with the term “nanotechnology” may lead to stronger opinions, either positive or negative. Food industry players could turn their attention to explain concepts and benefits, as well as the risks associated with nanotechnology, to encourage consumers to form their own educated opinions.

CONCLUSIONS

The results of this research showed that nanotechnology would be more easily accepted by consumers if it is applied to packaging rather than if it is directly applied to food. Moreover, when consumers perceive potential

benefits, there may be more openness to new technologies.

If consumers were to buy food obtained or packaged using nanotechnology, more than half (54%) of the participants in the study would trust a large, well-known company detrimental to new companies that specialize in food with special features.

Familiarization with the term "nanotechnology" can lead to stronger opinions, either positive or negative. Food industry players could turn their attention to raising awareness about concepts and benefits, as well as about the risks associated with nanotechnology, to encourage consumers to form their own educated opinions.

Such results may indicate an early openness from the consumers side towards nanoengineering in general and a first step in overcoming food neophobia.

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