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Perceptions of nanotechnology utilization in food: a pilot study

Urša Kogovšek | Boris Kovač | Katarina Babnik

University of Primorska, Faculty of Health Sciences, 6310 Izola, Slovenia.

Correspondence
Urša Kogovšek, Faculty of Health Sciences, 6310 Izola, Slovenia.

Email:ursa.kogovsek@gmail.com

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Abstract
Nanotechnology is a science field that includes research and applications carried out in the sphere of below 100 nanometers. Nanofood is the result of the usage of nanotechnology in food production, processing, and packaging. The paper presents results of a pilot study on perceptions of nanotechnology and its use in food production. A questionnaire was developed for the purpose of the study that measured knowledge, perceptions and attitudes towards nanotechnology and nanoproducts in general and in food industry. The results of the analysis suggested lack of knowledge about nanotechnology and its utilisation in food production. Motivation of respondents to purchase nanoproducts is low, mostly due to perceptions of possible changes in food caused by the use of nanotechnology. The respondents are aware of their poor understanding of nanotechnology and perceive potential risks related to the utilisation of nanotechnology. Education of consumers in relation to nanotechnology and its utilisation in manucaturing, especially in food production, is a necessary step in future development of this field.

1. INTRODUCTION

Nanotechnology and nanoscience are describing concepts at the level of atoms, molecules into macromolecules [1]. Nanoparticles are defined as particles that measure in at least one dimension of 100 or less nanometers [2]. Nanoparticles are the building blocks of nanomaterials and are subject to exploration and use in nanosciences and nanotechnologies [1]. Nanotechnology enables the acquisition of new, more powerful, lighter and cheaper materials [3]. Nanotechnology gives possibility to increase the nutrition value of food, to slow down the aging-related changes of food, and can be effectively utilised in the process for cleaning air and water [3]. Natural nanoparticles are generated with erosion; they are present in desert dust, viruses and volcanic eruptions; however engineering nanoparticles are produced deliberately [4]. Engineering nanoparticles can be found on the market today in pigments, cosmetics, food, detergents, cleaners, pesticides and many other products [4]. The chemical treatment on the surface of engineering nanoparticles enables them to aggregate into larger clusters. Several types of engineering nanoparticles are already in use. Depending on the chemical composition, these nanoparticles could be metals, metal oxides, carbon particles, polymeric particles and hybrid nanoparticles [4]. Nanotechnology enables a variety of new techniques in the process of production, processing and packaging of food. Nanotechnology has unpredictable possibilities to create new products. Nanofood denotes foods that are produced, processed or packaged using nanotechnology or in which nanomaterials are applied [4]. The use of nanomaterials in the food industry could be found in packaging and wrapping materials. [1]. Silicon oxide nanoparticles, nano-silver, nano-composites with natural biodegradable polymers and similar materials are already applied [1]. Various materials, pre-treated and reduced in a nanodimension, can be find in food products in order to maximize freshness, colour and improve the taste [5]. By applying nanocoatings to meat, cheeses, fruits and vegetables, moisture loss could be prevented and the influence of the atmosphere on the food reduced [1]. A well-known example is apples waxing. Nanocoatings also convey colours, flavours and may contain anti-oxidants, vitamins, minerals, enzymes, fatty acids and coenzyme Q10 [1]. The use of nanotechnology in the food sector is in the development phase. In practice the application of nanotechnologies exists in food packaging as well as in the production of materials that come into contact with food [6]. Nanomaterials can pass into the human body through the skin, oral breathing or ingestion [7]. Furthermore, they can pass into the bloodstream, brain, liver, heart, lung and the fetus [8]. For now, the impact of nanomaterials on the human body is not clear [8]. The progress of nanotechnology depends on public (customers) attitudes towards its use. People in general are not sure about the risks and benefits of nanotechnology, therefore it is unclear in whose favour they could decide [9]. The concept of nanotechnology is still unknown to a large number of people and also those people who have heard about nanotechnology have poor knowledge about it [10]. Most people do not have clear and defined attitudes towards nanotechnology [10]. Population has negative attitudes toward food and cosmetic products manufactured using nanotechnology [11]. [12] in his study determined that people are concerned about the use of nanotechnology in food and food packaging. Such concerns can be the result of lack of public awareness about nanotechnology in general or a poor understanding of nanotechnology use in food industry.

Examining consumers' beliefs and attitudes towards the use of nanotechnology is a relatively new field of research. We decided to empirically examine the beliefs and attitudes of consumers (general and not professional population) towards various aspects of the use of nanotechnology in manufacturing, mostly in food production. The purpose of the research, conducted in Slovenia, was to describe consumers' beliefs and attitudes towards the use of nanotechnology in general and in food production. We tried to answer the following research question: what are the consumers' beliefs and attitudes towards nanotechnology and its use in food production?

2. METHODS

We carried out a research using a non-experimental quantitative approach. We conducted a survey study. For research purposes, we designed a questionnaire that measures beliefs and attitudes towards nanotechnology and its applications in food production.

2.1. Sample

The study was carried out on a purposive sample of adults (young adults and working-age population). The study involved 114 participants: 72 of the participants were students and 42 were employed adults, 29 of them were men and 85 were women. On the questions about the achieved level of education 108 participants responded: 5 respondents had completed vocational high school education, 73 respondents had completed general secondary education, 29 of the respondents have higher education and one participant has a PhD. The average age of the respondents was 29 with a standard deviation of 11 years.

2.2 Instruments

On the basis of previous studies [9]; [10]; [11]; [12]; [13] we developed a questionnaire to measure beliefs and attitudes towards nanotechnology and its use in food production. The questionnaire consisted of closed-ended questions (items) in which participants responded on a five-point grading scale (frequency, level of acceptability, level of agreement). The questionnaire included 6 parts:

(i) Knowledge of nanotechnology application (4 items);
(ii) Willingness to purchase the product manufactured with nanotechnology or containing nanoparticles (4 items);
(iii) Nanotechnology and acceptance of food products change (8 items);
(iv) Attitudes towards the use of nanotechnology and nanoparticles in food production (6 items);
(v) Attitudes towards the use of nanotechnology and nanoparticles in general (4 items) (adapted from Zimmer et al., 2009).
(vi) Demographic data: gender, age, education, field of study, work experience and field of work.

2.3. Data collection and analysis

Before carrying out the research we obtained needed permissions (from the faculties' management and individuals participating in the study). We calculated the univariate (arithmetic mean, standard deviation), bivariate (correlation coefficients) and multivariate statistical methods (ANOVA) from the data gathered through the questionnaires.

3. RESULTS

In the first part of the questionnaire respondents were asked: "Have you ever heard of nanotechnology in the following areas?" Participants were asked to respond on a five-point scale of frequency, where 1 meant that they had never heard of nanotechnology and 5 that they often heard of nanotechnology. Areas in the questionnaire were related to medicinal products (drugs), food, cosmetics and technology. As can be seen from Table 1, the participants often heard for the use of nanotechnology in the field of engineering/technology (M = 3.46; SD = 1.56), and least often in the field of food (M = 2.04; SD = 1.04).

In the second part of the questionnaire, the participants were asked about their willingness to buy different types of products prepared with the help of nanotechnology or products containing nanoparticles. Participants evaluated the items on a five-point scale of frequency, where 1 meant that they would never buy a product that has been prepared with the help of nanotechnology or containing nanoparticles and 5 meant that they are certainly willing to purchase such a product.

Table 2 shows that respondents are most inclined to purchase medicinal products (drugs) (M = 2.82; SD = 1.32) and least inclined to purchase of food supplements (M = 2.18; SD = 1.18), containing nanoparticles or produced with nanotechnology.

In the third part of the questionnaire the participants were asked about acceptability of changes on food products produced with the utilisation of nanotechnology. Participants evaluated the items on a five-point scale of frequency, where 1 meant that the application of nanotechnology to change certain properties of a food product is "unacceptable", and 5 meant that the use of nanotechnology to change the specific features of the product is "very acceptable".

As can be seen from Table 3, the use of nanotechnology is most acceptable for the purpose of increasing the food nutritional value (M = 3.11; SD = 1.44), for functional ingredients improvement (M = 3.56; SD = 1.35), food safety improvement (M = 3.72; SD = 1.34), and for improvements of food asked to respond on a five-point scale of frequency, where 1 meant "never" and 5 meant "certainly." Through these set of items we tried to established attitudes towards the use of nanotechnology and nanoparticles in food production.

Table 4 shows that the participants have production and packaging technology (M = 3.39; SD = 1.31). The use of nanotechnology is less acceptable for achieving: better appearance (M = 2.23; SD = 1.28), food taste improving (M = 2.44; SD = 1.36), longer shelf life (M = 2.89; SD = 1.42) and lower prices of the product (M = 2.56; SD = 1.43).

In the fourth part, the participants were asked: "Do you have any concerns about the use of nanotechnology and nanoparticles due to the following statements?" Participants were asked to respond on a five-point scale of frequency, where 1 meant "never" and 5 meant "certainly." Through these set of items we tried to established attitudes towards the use of nanotechnology and nanoparticles in food production.

Table 1: Knowledge of nanotechnology application in everyday life

Nanotechnology application	Proportion of answers (%)					M	SD
	1	2	3	4	5		
Medicinal products (drugs)	37,7	16,7	24,6	15,8	5,3	2,34	1,27
Food	37,7	32,5	19,3	8,8	1,8	2,04	1,04
Cosmetics	36	18,4	21,1	17,5	7	2,41	1,32
Engineering Technology	21,1	8,8	10,5	22,8	36,8	3,46	1,56

Legend:M..arithmetic mean; SD..standard deviation

Table 2: Willingness to purchase the product, which is manufactured using nanotechnology or containing nanoparticles

Willingness to purchase the product	Proportion of answers (%)					M	SD
	1	2	3	4	5		
Medicinal products (drugs)	18,4	26,3	26,3	13,2	15,8	2,82	1,32
Food	32,5	29,8	23,7	8,8	5,3	2,25	1,16
Cosmetics	36	30,7	18,4	9,6	5,3	2,18	1,18
Engineering/Technology	23,7	17,5	31,6	17,5	9,6	2,72	1,27

Legend:M..arithmetic mean; SD..standard deviation

Table 3: Nanotechnology and acceptance of food products change

Nanotechnology and acceptance of food products change	Proportion of answers (%)					M	SD
	1	2	3	4	5		
Food appearance improvement	38,6	24,6	21,1	7	8,8	2,23	1,28
Food taste improvement	33,3	23,7	20,2	11,4	11,4	2,44	1,36
Food nutritional value improvement	21,1	11,4	26,3	18,4	22,8	3,11	1,44
Shelf life improvement	22,8	18,4	23,7	16,7	18,4	2,89	1,42
Functional ingredients improvement	11,4	9,6	24,6	20,2	34,2	3,56	1,35
Food safety improvement	9,6	8,8	22,8	17,5	41,2	3,72	1,34
Decrease in food price	33,3	17,5	23,7	10,5	14,9	2,56	1,43
Improved sustainability of food and packaging production technology.	12,3	11,4	26,3	25,4	24,6	3,39	1,31

Legend:M.. arithmetic mean; SD..standard deviation

Table 4: Attitudes towards the use of nanotechnology and nanoparticles in food production

Items	Proportion of answers (%)					M	SD
	1	2	3	4	5		
I do not want nanotechnology to be used in food production	16,7	24,6	29,8	16,7	12,3	2,83	1,25
The use of nanotechnology in food production is acceptable.	18,4	39,5	24,6	11,4	6,1	2,47	1,11
I would consume the food without hesitation if I knew it was produced using nanotechnology.	24,6	37,7	22,8	11,4	3,5	2,32	1,08
My knowledge of nanotechnology is too modest to decide on the consumption of foods that are also produced by use of nanotechnology.	8,8	11,4	17,5	21,9	40,4	3,74	1,33
The use of nanotechnology in food production can have negative consequences for human health.	6,1	20,2	49,1	7,9	16,7	3,09	1,09
The use of nanotechnology in food production can have negative consequences for the environment.	5,3	26,3	45,6	11,4	11,4	2,97	1,03

Legend:M.. arithmetic mean; SD..standard deviation

Table 5: Attitudes towards the use of nanotechnology and nanoparticles in general

Items	Proportion of answers (%)					M	SD
	1	2	3	4	5		
The development of nanotechnology is important, but taking account of its potential risk.	4,4	7	21,9	26,3	40,4	3,91	1,14
It is good to live in a world which is constantly progressing thanks to the development of nanotechnology.	6,1	7,9	31,6	27,2	27,2	3,61	1,15
Nanotechnology opens up new possibilities for technical development.	3,5	5,3	25,4	30,7	35,1	3,89	1,06
I am not in favour of modern technologies, such as nanotechnology.	19,3	23,7	38,6	11,4	7	2,63	1,13

Legend:M... arithmetic mean; SD..standard deviation

The item: ''My understanding is too modest to decide on the consumption of foods that are produced with the help of nanotechnology.'' is assessed with the highest average mark. (M = 3,74; SD = 1,33). This suggests that participants are aware on their lack of knowledge about nanotechnology and the consequences of its use. It is difficult for them to decide on whether for example they will consume food produced by nanotechnology processes.

The fifth set of questions asked participants if they agree with particular statements relating to nanotechnology in general. This part of the questionnaire aimed to measure respondents' attitudes towards the use of nanotechnology in general. Table 5 shows that most respondents agreed with the statement: "The development of nanotechnology is important, but without forgetting its potential risk." (M = 3,91; SD = 1,14). Nevertheless, the answers of the respondents show relatively positive attitudes towards the development of nanotechnology in general.

Due to the diversity of the sample (education, age and sex), we examined the role of demographic variables in beliefs and attitudes toward nanotechnology. For each of the part of the questionnaire (knowledge of nanotechnology application in everyday life; willingness to purchase the product manufactured with nanotechnology or containing nanoparticles; nanotechnology and acceptance of food products change; attitudes towards the use of nanotechnology and nanoparticles in food production; attitudes towards the use of nanotechnology and nanoparticles in general), we calculated the average score for the included items. Depending on the measurement level of demographic variables we analysed the possible influence of gender, age and attained educational level on various aspects of beliefs and attitudes towards the use of nanotechnology. The analysis showed that gender is not an important factor in the differences in beliefs and attitudes toward nanotechnology (F statistic is significant at $p > 0.05$ for all five parts of the questionnaire). Level of education is related only to one aspect of beliefs and attitudes, namely to attitudes towards the use of nanotechnology and nanoparticles in food production ($df = 112$; $F = 3,735$; $p = 0,007$). Spearman's rank correlation coefficient between age (expressed in years) and the average ratings for each part of the questionnaire shows no significant correlations - all correlations were significant at $p > 0.05$.

4. DISCUSSION

The aim of our study was to describe the beliefs and attitudes of consumers towards nanotechnology and its applications in food production. On a sample of general young adults and middle aged population we tried to describe the perceptions related to nanotechnology and its utilisation in various fields, with a focus on the field of nutrition and food science.

The results of the study show that nanotechnology is still quite an unknown area for respondents. Most respondents are acquainted with the use of nanotechnology in the field of engineering/technology. They have rarely or never heard about the use of nanotechnology in food production, pharmaceutics and cosmetics. Analysis of the results shows that respondents are most inclined to purchase medicinal products and cosmetics produced by the use of nanotechnology. The survey participants are less inclined to purchase food and dietary supplements produced with nanotechnology. Respondents rate as the most acceptable those changes in food products that improve their safety and increase their functional ingredients. The least acceptable change produced with nanotechnology is the appearance of the food.

We found that respondents were aware of their lack of familiarity with the nanotechnology and its implications. Respondents evaluate that do not have enough knowledge about nanotechnology to be aware of the consequences of the use of nanotechnology to human health and the environment. We found that respondents evaluate the development of nanotechnology as important, but are aware that the use of nanotechnology has certain risks. Respondents are aware that nanotechnology brings many opportunities to technical development. Research participants are reserved towards nanotechnology and its application, probably due to lack of knowledge on the subject. Similar results were attained also in previous studies. On a sample of inhabitants [11] found negative attitudes towards nutrition and cosmetic products manufactured with the use of nanotechnology. [12] found that the use of nanotechnology in food and food packaging raises concerns of the consumers. [9] argue that people are not sure about the risks and benefits posed by

nanotechnology. [10] note that to a significant number of the population nanotechnology is still unknown and that most people do not have clearly defined attitudes towards nanotechnology. Similar conclusions can be drawn also from our study. Nevertheless, such conclusions cannot be generalized to the entire population since the sample was too small and to demographically diversify. New studies of knowledge, beliefs and attitudes towards nanotechnology are needed in the future. Consumers should also be properly informed and educated nanotechnology and its application in food production and in everyday life.

Nowadays nanotechnology and its applications give us many opportunities for development; however the consequences of its use would require further research. Consumers have an important role in regard to the acceptance and utilisation of nanotechnology products. The results of our study performed on a sample of general adult population suggest lack of knowledge about nanotechnology. In the future the education of consumers and further activities in the development of legislation on nanotechnology and nanoparticles application should be intensified. The legislation is important because consumers' perceptions of safety are related also to the degree of regulation and formalisation of the nanotechnology and nanoparts application in manufacturing every day products.

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