Acceptance of nanotechnology in the food sector – A review

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Table of content

Abstract

Nanotechnology in general and especially in the food sector is met with hesitation by consumers. This is due to numerous obstacles preventing nanofood and -packaging from being widely accepted. They cover a range from broader concepts like risk/ benefit perception to narrower ones like price. Hence, the objective of this literature research was to reveal as many contributing factors as possible and scrutinize the existing literature in search for them. Subsequently, 37 papers have been systematically reviewed using 18 codes to identify the factors' importance. The affect- acceptance chain, the demographic and psychographic findings were found to deliver interesting psychological insides which were presented in tables and analyzed. Resulting from this, affect was found to influence the product acceptance of nanofood and -packaging but it remains unclear if its effect is positive or negative. The review fostered previous findings which indicated that young, higher educated males are more accepting whereas older women are the most rejecting group. Adding to that, psychographics offer insights in to the reasons behind this phenomenon and why it might change. Finally, it is concluded that risk/benefit perception is the most important factor and demo- and psychographic reasons for that are scrutinized. The practical implication is the call for a research not only focusing on the individual reasons but also take the influence of society into account to disclose yet unknown factors and dynamics influencing the acceptance of nanotechnology in the food sector.

Status quo regarding nanotechnology in the food sector

"Nanotechnology" is a term used to describe a relatively new technology that concerns extremely small particles. These particles are at molecular level and get used to create desired traits of a product. Examples for that are increased stability or reactivity compared to similar products without nanotechnology. Nanomaterials were used a couple of hundred years ago in e.g. the fabrication of colored glasses for churches or the famous "Lycurgus Cup" without knowledge about the science behind it. That's why there is no undisputed starting point of this technology. Still, the idea of consciously crafting and using nanoparticles originated in 1959. In that year, Richard Feynman envisioned to consciously use particles at the molecular level when holding a talk in California. Roughly two decades later, it was possible to see nanoparticles with the help of the scanning tunneling microscope (STM) and the atomic force microscope (AFM). Finally, Norio Taniguchi named the particles he could see by using the new microscopes in the year 1981. It took another 10 years to

really get to a point where it was possible to make use of nanotechnology for commercial reasons. Since then, its use has dramatically increased as well as the investment in research.

Nanoparticles are in the range of 10^{-9} meters which equals to a ratio of one to one billion (1:1,000,000,000) if comparing a meter to a nanometer (*What is nanotechnology*, 2015). That's why there is high-tech needed to control matter at such a small scale and finally craft products incorporating nanotechnology (Mnuysiwalla et al., 2003). So, nanotechnology means the usage and crafting of particles at the molecular- or atom level which was made possible by advances in microscopy 35 years ago (*What is nanotechnology*, 2015). From the start, the discovery was met with increasing investments to research. An example is the budget of the environment, health and safety (EHS) department of the U.S. based National Nanotechnology Initiative (NNI) which was state-funded with about 1 billion U.S. dollars from 2006 to 2015 (*What is nanotechnology*, 2015). This tremendous investment in research emerged from high expectations due to renowned scientists claiming that nanotechnology would increase quality of life drastically. This is thought to be reached due to its wide field of usage reaching from medical applications to gas leakage sensors for pipelines (Mnuysiwalla et al., 2003). Despite this, knowledge about nanotechnology in the broader public is rather small. (Yawson & Kuzma, 2010).

Amongst a wide range of applications, it is also incoprorated by the food industry due to its "potential to improve the quality of food due to improved sensory appeal, as well as better health and safety" (Stampfli et al., 2010, p. 2). More specifically, the research focuses mainly on food packaging due to the numerous benefits it provides in terms of stability, (health) safety and practicality (Stampfli et al., 2010). Aligning with this is the NNI, which also ascribes numerous benefits to nano-based food packaging focusing on the antimicrobial and reduced gas leakage properties (*What is nanotechnology*, 2015). However, there is also an increased use of nanotechnology in food processing over the years. This is due to its properties in preserving certain constituents of food and nanosensors which can serve as warning systems to for example indicate contamination (Stampfli et al., 2010; *What is nanotechnology*, 2015).

Problem statement

The problem associated with all those promising achievements is that there are real and perceived dangers of nanotechnology in the food sector. That's why there are increasing numbers of scientific

publications dealing with the eventually problematic consequences arising from the use of this technology (Mnyusiwalla et al., 2003). Yue et al. (2015) found that nanotechnology in food is not very well perceived with most consumers but there is still fewer concern than with genetically modified (GM) foods. Since "[…] genetic modification, biotechnology, and nuclear energy have met with considerable public resistance" (van Giesen et al., 2016, p.2), it is important to prevent major rejection like with GM food (Stampfli et al., 2010). A spillover of this sentiment or the same pitfall are feared to happen to nanotechnology as well (Frewer et al., 2014). But this doesn't mean that the majority of consumers is generally averse towards those technologies.

Despite a generally higher acceptance towards "nanofood" (Yue et al., 2015, p. 17), there is also a considerable group of people (~ 25%) who completely reject food innovations due to their preference for natural food. Still, consumers are very diverse in their perception and there are more innovation friendly segments. But there are numerous obstacles for the acceptance of nanotechnology in the food sector including concerns about price, health, benefits (and risks) and comfort (Yue et al., 2015). So despite the concerns about nanotechnology in the food sector, *research about potential risks* is lagging behind both in terms of interest and budget for research (Mnyusiwalla et al., 2003). So research is too focused on possible applications and not on how to reach acceptance of the existing concepts. Concluding from that, one of the key issues of nanotechnology in food and packaging remains stakeholders' efforts to increase product acceptance (Yawson & Kuzma, 2010; Stampfli et al., 2010). This is especially true in Europe because Europeans are more averse towards nanotechnology both in general and with regard to nanofood and packaging (Stampfli et al., 2010; Yawson & Kuzma, 2010; Yue et al., 2015).

Major issues regarding the product acceptance of food (related) products can be summarized by trust issues, institutional uncertainties, lack of information, people's and environmental health concerns and stakeholder's perceptions (Yawson & Kuzma, 2010). Moreover, there is a range of indicators for nanotechnology acceptance such as stance towards GM technology and "green" and beneficial food preference (Stampfli et al., 2010). Another major problem seems to be the lack of information about nanofood and -packaging in a majority of the population as pointed out by Stampfli et al. (2010). Overall, nanotechnology in food is mostly being rejected whereas it is acceptable for a majority of people if it is used in packaging (Stampfli et al., 2010). Summarizing, there is a multitude of obstacles preventing consumers' acceptance of nanotechnology in the food sector. However, to this date there is no literature review including all these factors. Concluding from this, the goal of this literature review is to explore possible obstacles and determine their impact on product acceptance. Adding to that, causal chains mentioned above will be scrutinized and unique findings from the literature will be presented.

Research question

Following the line of argument of the problem statement, the research question is:

What are obstacles for the product acceptance of nanotechnology in the food sector?

Theoretical framework

Trust was found to be a major factor for the product acceptance of nanotechnology in the food sector (Siegrist et al., 2007; Yawson & Kuzma, 2010; Stampfli et al., 2010). This is due to its effects, whether they are positive or negative, which cannot be perceived directly and therefore consumers are forced to trust information given by the producers. When trust is established, *information* about a product is interpreted favorably. Also, *affect* is a crucial factor when perceiving *risks* which is due to the so called "affect heuristic" (p. 2). This means that perception is based on the affect a consumer has towards a technology (Siegrist et al., 2007). These findings get supported by Ronteltap et al. (2011) who finds this to be especially true for consumers in the Western sphere, namely Europe and the US. Besides that, consumers rely more on affect than *cognition* when perceiving nanotechnology (van Giesen et al., 2016). The model for the affect risk/ benefit perception done by Siegrist et al. (2007) is depicted in figure 1.

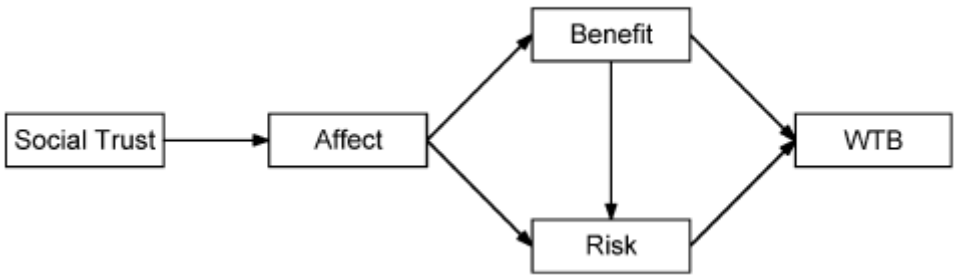

Fig. 1 Proposed model explaining willingness to buy nanotechnology foods according to Siegrist et al. (2007).

Additionally, there are strong impacts from both *perceived benefits* and *perceived risks* on product acceptance of nanofood and packaging (Stampli et al., 2010). Thus, the perception of risks versus benefits is again influenced heavily by (*social) trust* (Siegrist et al., 2007).

Another important factor is the *preference for healthy and natural food* which is perceived to be opposing nanotechnology in the food sector (Stampfli et al., 2010). A further factor mentioned by multiple researchers is *perceived distance/ proximity* of nanoparticles particles. It means that nanoparticles are seen as being able to enter the organism of the consumers and this might be a health risk perception-wise (Stampfli et al., 2010). This applies only to nanotechnology in the food itself (Frewer et al., 2014; Steenis & Fischer, 2016). Both the preference for healthy food and the distance aspect can be linked to *risk perception* which itself is based on *affect* which is higher in the abstraction hierarchy (Ronteltap et al., 2011). Aligning with that, Yue at al. (2015) found that there are individual traits expressing themselves in major societal groups like general innovation rejection. That's why eventually those population groups can't be included for market segmentation (cf. Stampli et al., 2010). A further factor related to that is the *attitude towards GM* food(s) (Yue et al., 2015) because the perceived risks and benefits of nanotechnology are associated with the ones of GM foods due to shortcuts as pointed out by Stampfli et al. (2010). The reason for that is that there is a semantic association with that term triggering the concept of unfamiliar risks. This is called the "semantic network model" (Stamfli et al., 2010, p.11).

It was additionally found that *information* has a big impact on the acceptance of nanotechnology. A first related finding was that the fewer information the consumer has, the higher the extent to which he or she relies on feelings and the aforementioned (lack of) *knowledge* (Stampfli et al., 2010). Information is thought to be a big limitation overall in terms of product acceptance. It is frequently emphasized in contemporary literature regarding nanotechnology in the agrifood sector (Stampfli et al., 2010; Yawson & Kuzma, 2010; Siegrist et al., 2007; Yue et al., 2015). Another concept related to this is *familiarity* with nanotechnology which au contraire has no significant influence on the perception of nanotechnology in food or its packaging (Steenis & Fischer, 2016). Leaning towards this concept is the one of *experience* which got mentioned by van Giesen et al. (2016). Thereby, it was specified that the *lack of experience* is negatively correlating with the acceptance of nanotechnology. This factor might decrease with time since nanotechnology is fairly novel. According to Giesen et al. (2016), there is no correlation between knowledge and relying on affect or cognition.

The issues of information, social trust, health concerns are also mentioned by Yawson and Kuzma (2010). They also add insufficient *stakeholder engagement* to the issues nanotechnology in food and -packaging is facing. Aligning with that, other research suggests to counter poor stakeholder engagement by "social inclusivity" (Frewer et al., 2014, p. 12) which means making efforts to involve consumers. That is beneficial in basically all stages but namely the phase before the product launch (Frewer et al., 2014). As an addition to that, stakeholder engagement is interwoven with *institutional uncertainty* which covers a broad range from education to regulation (Yawson & Kuzma, 2010).

Low income and education, high age and female gender are *demographic factors* having a negative correlation with product acceptance of nanotechnology according to Yue et al. (2015). Besides that, *ethical issues* play another major role in this puzzle and they are interlinked with information, trust, affect and health concerns (Ronteltap et al., 2011; Frewer et al., 2014). Additionally, there are more unique findings on the matter that should be taken into account when reviewing the literature such as broader factors such as *emotions, framing, situation, motivation and cognitive abilities* as listed by Ronteltap et al. (2011). Further, it should be noted that *time* plays an important role in attitude formation. Therefore, it is a major factor for product acceptance regarding nanotechnology (van Giesen et al., 2016). Finally, Frewer et al. (2014) mentioned *price* as another influential determinant.

Method

With respect to the research question(s) and the hypotheses, an exploratory research was conducted in the form of a literature review. The search engines used was the Scopus. This was done because this data base only contains literature that is already reviewed. What's more is that it got Social Sciences as a main field of interest. The literature review was not limited regarding the year of publication due to (conscious) usage of nanotechnology being relatively recent. To get relevant information, a list of Boolean operators was created based on the introduction and the theoretical framework which will be depicted in table 1.

Crucial parts	*Search terminologies*
1. Nanotechnology	"nano*" AND…
2. Product acceptance	"acceptance" OR "Willingness-to-buy" OR "WTP" OR "Willingness-to-accept" OR "WTA" AND…
3. Food sector	"food*" OR "agri*"

Table 1 Search terms in combination with Boolean operators and Asterisks.

"Nanotechnology" was chosen to be a crucial factor since it is the main factor and starting point of the research. "Product acceptance" is the second important factor which also limits the results. But to really narrow the results to fit this review the part "Food sector" is of major importance.

The boolean operator "AND" was used to narrow the results to articles dealing with the three parts deemed crucial. Within those limitations, the Boolean operator "OR" was used to broaden the results

to acquire as much information as possible. Asterisks (*) were used to not miss words being similar but having different endings like nanotechnology and its plural nanotechnologies for example. The quotation marks were used so that the data bases don't automatically add an "AND" between the words thus narrowing the results and distorting the context.

The first part "Nanotechnology" has similar terms that were mentioned in the literature such as "nano", "nanotech" and "nanotechnology". "nano*" was chosen to also include papers with that terminology. "Product acceptance" has similar and abbreviated terms as well which were reoccurring in the literature like consumer- or market acceptance. Therefore, the term "acceptance" was used to include them all. Additionally, the terms "Willingness-to-buy" and its short form "WTP", "Willingness-to-accept" and its short form "WTA" were used. The third part was the linkage to the food sector. To find sufficient results, the search term "food*" was used to find all food related outcomes. Another term that appeared frequently in the literature was agrifood that is why the search term "agri*" was used as well.

After conducting a research with the following terms a total of 114 papers were found and their insightfulness for the research evaluated. This happened via reading the abstracts. If an abstract was including insights about all three of the main parts, it was added to the research. Following that, the findings not excluded were read to see in how far they are useful beyond the quick screening.

The *quick screening* was done by using the following exclusion criteria:

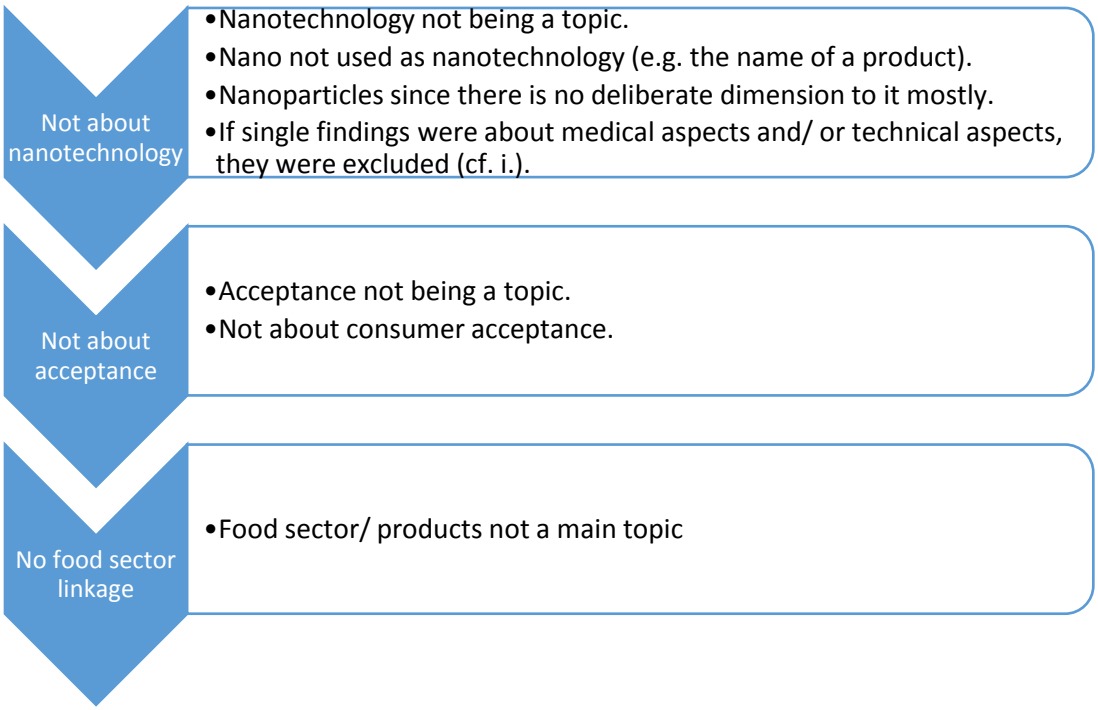

Fig. 2 Exclusion criteria

The findings of the theoretical framework were used for coding the later results. Thus, it should be noted that certain constructs are interlinked e.g. proximity and risk/ benefit perception. But they were divided since they were named independently as contributing factors. It is important to note that the coding was not used word-for-word but synonyms were also included. This was done to ensure that no contributions were overlooked.

Coding of the factors

1. Trust
2. Information/ Knowledge
3. Affect/ Emotions
4. Risk/ benefit perception (health, society and environment)
5. Cognition/ Cognitive abilities
6. Preference for healthy/ organic food
7. Particle proximity (perceived)
8. Awareness
9. Familiarity
10. Experience
11. Stakeholder Engagement (SE)
12. Institutions and regulation
13. Attitude towards GM food
14. Demographics (gender, income, age)
15. Psychological factors (ethical/ moral factors/ attitude/ motivation)
16. Framing
17. Situational factors (e.g. time)
18. Price/ WTP/ WTB

Results & Analysis

On basis of the exclusion criteria, 66 were excluded and an additional 7 were inaccessible. So, a total of 41 papers were left to be summarized and coded. After reading the papers, another 4 papers were excluded because of unfitting content. The remaining 37 papers have been included in this review.

Figure 3 is a histogram showing the publication year distribution of the papers that were finally included:

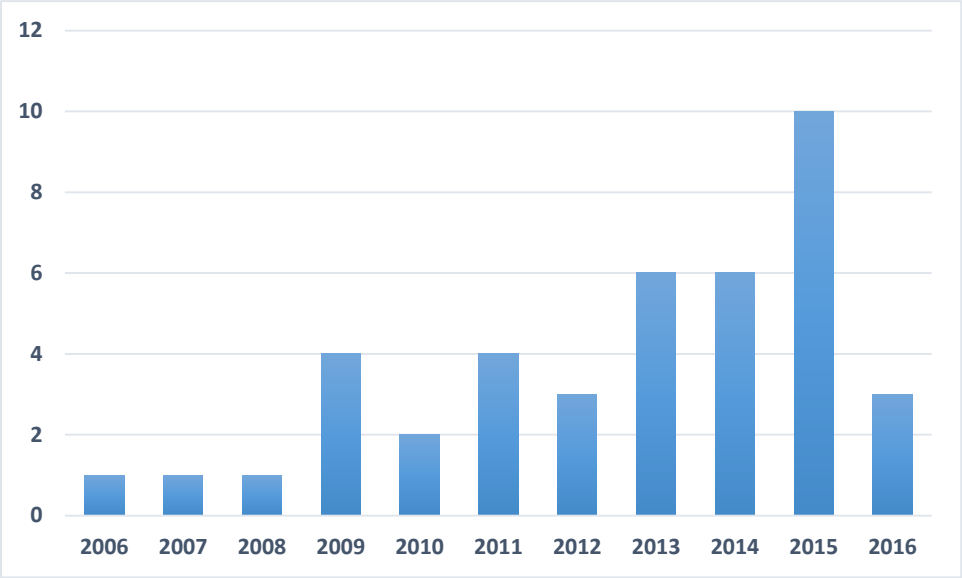

Fig. 3 Included publications sorted by year.

As can be seen from this, the earliest result included was a paper from 2006 which mainly dealt with GM food perception spillover to nanofoods and -packaging (Ebbesen, 2006). The latest results were from 2016 but the total number of included number is evidently lower than of 2015. This could have been due to the year 2016 not being over and publication taking a while. The last literature review took place at the 14th of November, 2016.

Overall frequencies for the 18 factors were found for the 37 examined papers. The most emerging factor by far was risk/benefit which appeared 36 times which would support e.g. Gupta et al. (2013) claiming it is the most important factor. This is possibly due to it covering a broad range of factors and being directly related to product acceptance. Next, the second most appearing factor was information/ knowledge with 25 counts. Information was hence seen as having a negative influence by most researchers with Yawson & Kuzma (2010) and Fischer et al. (2012) being the outliers stating ambiguous impact (positive and negative influence). The reason why information was counted that often is that information has a major influence on risk/benefit perception and covers other related topics such as price. Following this, trust and psychographics were appearing each 19 times. Psychographic factors are having both negative and positive influences due to their broad range as will be depicted in table 4 and discussed. Institutional uncertainties and regulations is ranked fifth in terms of frequency with 15 counts. They were found to be intermingled with trust. The next factor

was demographics which was mentioned as a factor in 13 papers. The demographic findings will be scrutinized in table 2. After that, price was named as a factor 11 times in the literature. By means of this, one can expect that price is a general limitation for a lot of consumers and this might be the reason why it was not taken into account in more papers. Affect/ emotions, proximity, familiarity and stakeholder engagement were all counted 10 times. 9 times preference for healthy food has been named as a factor. Awareness was brought up 8 times and attitude towards GM food 6 times. Attitude towards GM food and preference for natural and healthy food are related as will be shown in figure 4. By this means, preference for healthy and organic food is seen as opposing to GM food by most consumers (Stampfli et al., 2010). Framing and situational factors each emerged as factors 4 times. Both cognition/ cognitive abilities and experience were named only one time. The last three numbers are not too surprising because most of the included papers were surveys so it is hard to frame, present different situations and determine cognitive abilities.

The results were depicted in figure 4 and main categories have been added for a better overview.

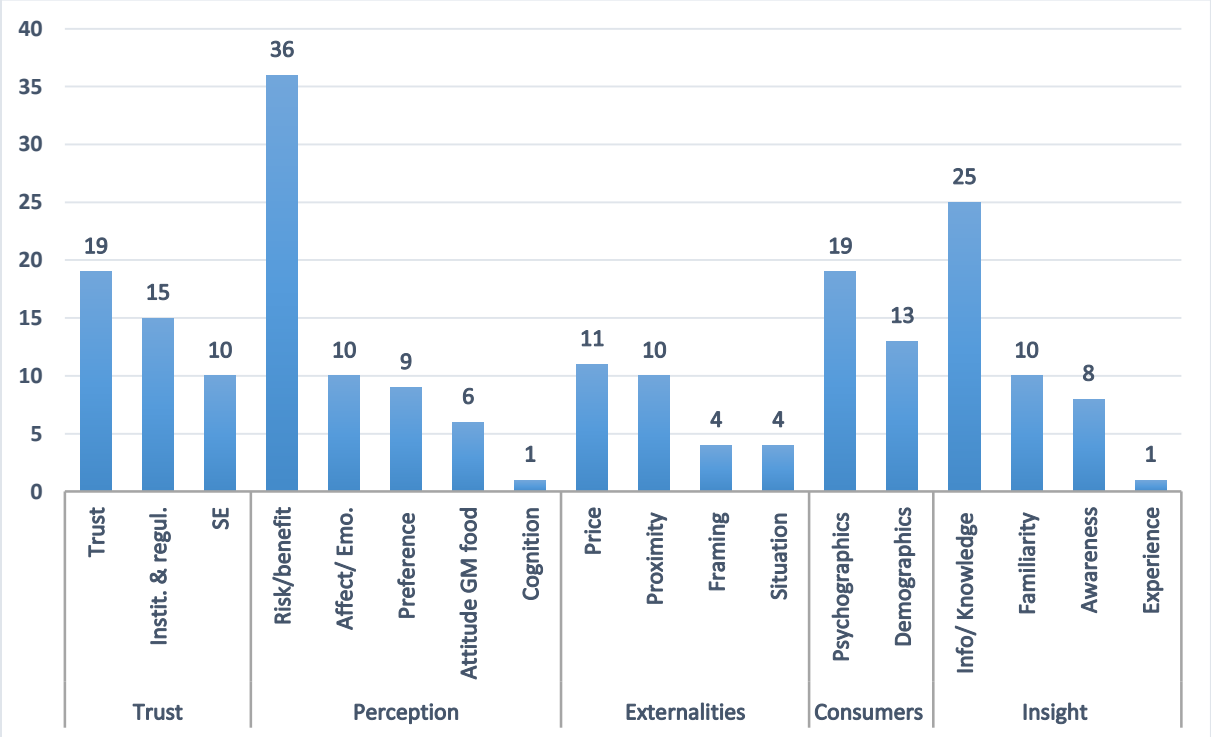

Fig. 4 Frequencies of the coded factors found in the literature grouped into root categories.

Looking at the broader categories, “perception” scored the highest with 62 counts with risk/ benefit perception being the dominant contributor. Perception is often a final product of the other factors and a negative perception is contrary to product acceptance. “Trust” related issues were counted 44 times despite having only 3 contributing factors. Hence, trust is a very important category. This main category is closely linked to “insight” which scored equally high. This aligns with the model Siegrist et

al. (2007) proposed which sees trust related factors as a major influence for the evaluation of information. “Consumers”- related terms were counted 32 times which is very high for having only two contributors. This shows that the psycho- and demographics are worth a research of their own since they are good predictors for consumer acceptance (Schnettler et al., 2013a, 2013b, 2014). “Externalities” were counted 29 times with price being the highest contributor closely followed by (perceived) proximity. Proximity is a factor which has the potential to significantly alter risk perception and is closely related which might be a reason why it was frequently appearing. Since it is an externality, it was not taken into the “perception” account. Summing up, the factors and categories are not loose concepts but should be seen as a network with product acceptance being the center.

Next to the general findings, individual findings for some factors were found to be major contributors to the acceptance of nanotechnology in the food sector. Those will be presented in tables 2, 3 and 4.

In table 2, the demographic factors were scrutinized.

Table 2 Demographics and their effect on acceptance of nanotechnology in the food sector (in chronological order).

Author(s) & year of publ.	Country & method(s)	Results
Gruere (2012)	Literature review	Education favors (high levels of) knowledge which might have a negative effect on acceptance.
Fischer et al. (2012)	UK, survey[s] (total N=618)	After providing risk/benefit information, higher educated respondents and young males tended to become more positive whereas the opposite happened in case of older, lower educated women.
Bieberstein et al. (2013)	France & Germany, experiment (N= 295)	French consumers are more open towards nano-fortification and less open towards nanopackaging compared to their German counterparts. The authors assumed that this is due to other cultures.
Schnettler et al. (2013a)	Chile, survey (N=400)	In developed countries, people are less willing to buy nanofood compared to -packaging. This might be reversed for developing countries.
Schnettler et al. (2013b)	Chile, survey (N=400)	Despite earlier findings in developed countries, the Chilean sample preferred nano-fortificated oil over conventional oil. Furthermore, marital status rather than age or gender was found to be a good predictor.
Schnettler et al. (2014)	Chile, survey (N=400)	Older people overall are neophobic which lowers acceptance of nanotechnology in the food industry. Higher overall status (income & education) equals a higher level of acceptance.

Wilcock & Ball (2014)	Literature review	Women have lower acceptance and confidence in the development of nanotechnology in the food sector.
Yue et al. (2014)	US, survey (N= 1.117)	The oldest and the youngest consumer segments have the lowest acceptance rates (mixed results). Still, older people are more adverse overall. Lower income and education are negatively correlated with consumer acceptance. Women tend to reject new technologies more often. Also, males are price-sensitive.
Vidigal et al. (2015)	Brazil, survey (N=389)	Brazilians were found to be more open to new (food-) technologies in comparison to Canadians and Australians. Gender, marital status and family size did not play a role, but age, education and income. Meaning the older, lesser educated and poorer someone is, the higher the possibility of rejection of nanofood and -packaging.
Giles et al. (2015)	Literature review	White males tend to have the lowest rejection rate regarding nanotechnology in the food sector and for technology in general.

As expected, demographics can have a high impact but there is a vast variety of explanations why. There is the finding that there is a difference between countries. Also, there are differences between neighboring countries which are both developed countries. Those are explained by cultural differences as can be seen in Bieberstein et al.'s (2013) research. What's more, there are differences between developed and developing countries. In developing countries there is a higher acceptance for nanofood compared to nanopackaging. The opposite applies for (most) developed countries (Schnettler et al., 2013a). Thus, one cannot conclude that there is a higher or lower general acceptance in developing countries compared to developed ones.

A consistent finding is that white males and consumers with a high socio economic status (education and income) tend to be more open towards nanotechnology in food and food packaging. It is highly likely that socio-economic status is the driving factor rather than race. Statistically, it still holds true due to more white males being represented at the socio-economic top. Besides that, it is noteworthy that males have a higher rate of acceptance than women who tend to reject more often (Yue et al., 2015). This is a consistent but unexplained finding. Another result is that "old" consumers are more neophobic and thus have lower acceptance probability. This is a very consistent and expected finding.

In table 3, individual findings on the causal chain between affect, information and risk/ benefit perception as described by Siegrist et al. (2007) have been examined.

Table 3 Risk/benefit perception and the effect of affect/ emotions on information evaluation (chronological order).

Author(s) & year of publ.	Country & method(s)	Results
Siegrist et al. (2007)	Switzerland, survey (N= 153)	Trust is a strong factor influencing information evaluation related to the risk/ benefit perception. In general, the affect-acceptance causal chain is negative.
Yawson & Kuzma (2010)	Globally, literature review, expert elicitations (N=21)	If trust is established, a positive affect occurs which hence mildens the effect of negative information and strengthens the one of positive information.
Frewer et al. (2011)	Literature review	A lack of stakeholder engagement leads to negative emotions and perception of the information and its sender regarding risk assessment & management.
Roosen et al. (2011)	Germany, experiment (N= 143)	Brief and simple to understand information has potentially negative impact on risk/benefit perception because it can scare consumers. The reaction is especially strong if health related information is involved.
Öner et al. (2013)	Turkey, survey (N= 324)	Affect positively influences information evaluation and therefore a better risk/ benefit perception ensues. This is opposed to Siegrist et al. (2007) findings.

It is important to note that this is an analysis of the model proposed by Siegrist et al. (2007) which roughly depicted the relation between trust → affect → risk perception → acceptance. It was found that his causal chain of affect influencing information evaluation and hence risk/ benefit perception was mostly supported. Although, not all of the other authors mentioned trust as having an influence on affect. As can be seen from this table, Öner et al. (2013) disagreed with Siegrist et al. (2007) in what was a follow up study. Aligning with Siegrist et al. (2007) are Frewer et al. (2011) and Roosen et al. (2011). So there is a majority of papers supporting the hypothesis that affect influences the effect of perceiving information negatively.

Summing up, there is an outlier with Öner et al. (2013). This might be due to other demographics or due to choosing a convenience sample. Also, it remains unclear if there is a cohort effect due to the researchers being in contact and Frewer et al.'s (2011) being a literature review referring to Siegrist et al. (2007) and putting lack of stakeholder engagement on the starting point of the chain. It should be kept in mind that the results are theoretical and have no empirical proof by for example experiments.

In table 4, psychographics and their influence on nanoproduct acceptance in the food sector were listed.

Table 4 Psychographics and their effect on acceptance of nanofood & -packaging (Ethical, moral, attitudinal & motivational factors) in chronological order.

Author(s) & year of publ.	Country & method(s)	Results
Ebbesen (2006)	Literature review	Moral factors such as ideals about nature and those derived from religion can outweigh trust.
Druckman & Bolsen (2010)	US, survey (N=621)	Consumers tend to use heuristics and shortcuts when judging about nanotechnology in the food sector. This causes cognitive dissonance which in turn lowers acceptance rates.
Stampfli et al. (2010)	Switzerland, survey (N=514)	Attitude towards technology was linked positively to perceived benefits and therefore acceptance.
Yawson & Kuzma (2010)	Literature review	When informing the public, ethical issues should be considered to prevent rejection.
Frewer et al. (2011)	Literature review	Psychological factors like values and fear have a major influence on trust. Trust influences risk/ benefit perception.
Lopéz-Vázquez et al. (2012)	Mexico, interviews (N=378)	The perception of having control is positively correlated to nanofood and -packaging acceptance. This is due to a decrease in perceived risk.
Fischer et al. (2012)	UK, survey[s] (total N=618)	Opinion leaders convince people to accept or reject. To develop trust in an opinion leader, similar values with him/her must be perceived. Besides that, information touching personal values have a higher influence on (non-) acceptance.

Ueland et al. (2012)	Literature review	Nanofood has the possibility to “provide pleasure through eating and socializing“ (p.1). Higher perceived risks cause fear and thus rejection.
Bieberstein et al. (2013)	France & Germany, experiment (N=295)	Traditions in a geographic region influence consumer choices. This is holds true regarding nanofood and -packaging.
Schnettler et al. (2013a)	Chile, survey (N= 400)	The more conservative, the lower acceptance of nanotechnology.
Coles & Frewer (2013)	Literature review	Ethical considerations about the feelings of “autonomy, malfeasance, beneficence and justice” (p.5) play an important role for the acceptance of nanofood and -packaging.
Schnettler et al. (2014)	Chile, survey (N= 400)	Conservative consumers have a lower acceptance rate regarding nanoproducts in the food sector. Food neophobia is a characteristic that has a strong impact on product acceptance.
Casolani et al. (2015)	Italy, survey (N= 221)	Basic values and beliefs about nature, tradition, science and the balance between those three influence nanotechnology acceptance. Traditionalists tend to reject nanofood.
Yue et al. (2015)	US, survey (N= 1.117)	Groups with the highest rejection rate were either very liberal or conservative. Still, conservative views appeared more often with rejecters. Conservative & highly educated people are more price sensitive. Religiousness plays no major role.

Giles et al. (2015)	Literature review	Conservatism is negatively linked to new product acceptance.
Sodano et al. (2016)	Italy, survey (N= 300)	Presenting nanoproducts as only functional is negative due to overlooking other functions food may have for people. Additionally, perceived loss of control and perceived lack of sustainability have strong negative effects on the evaluation of nanotechnology in the food sector.
Steenis & Fischer (2016)	Netherlands, experiment (N= 141)	The attitude towards nanotechnology in the food sector is just part of the overall attitude towards food products.

A general pattern here was that conservative consumers are less inclined to accept nanotechnology as put simply by Giles et al. (2015). The only study standing out and fitting at the same time is the one done by Yue et al. (2015). Their finding was that the more one leans to political extremes both liberal and conservative, the lesser acceptance. Aligning with the finding on conservatism, tradition was found to have a negative impact on nanotechnology in the food sector (Bieberstein et al., 2013). That was due to consciously implemented nanotechnology not being perceived as traditional. An explanation for that could lie in the nature of conservatism trying to preserve making it opposed to innovation and change. This is strongly linked to the findings about the demographic variable age since older consumers tend to be more conservative and opposed to new technologies which aligns with the demographic section. So, it is safe to say that those concepts are interlinked.

Another related point was general attitude towards technology. If that attitude is positive, acceptance is more likely to ensue and vice versa (Stampfli et al., 2010). It was found that values play an important role for product acceptance. This is due to them evoking feelings of similarity and trust (Fischer et al., 2012). Values play an important role for behavior in general so this result was expected to be found. This bears the possibility of influencing the evaluation on base of information positively. The results regarding the influence of religiousness are mixed (Ebbesen, 2006; Yue et al., 2015). This could be due to demographics of the sample meaning that eventually more secular and more fundamental people are not really scrutinized.

Ueland et al. found that an important factor is the socializing component given to food (consumption). Aligning with that, it was found to be an obstacle if the implementation of nanotechnology would be perceived as too or exclusively functional (cf. Sodano et al., 2016). Since food consumption often takes place in a social context like e.g. the daily dinner with close relatives, this finding is not very controversial. The lack of tradition was found to be entirely negative for more most people. Functionality on the other hand poses as both an obstacle and a chance.

Lopéz-Vázquez et al. (2012) and Sodano et al. (2016) also found that the feeling of control is positively related to product acceptance of nanofood and -packaging. The opposite applies for lack of control due to it being linked to a higher risk perception. Coles & Frewers' (2013) findings basically say that a perceived violation of universal principles will lead to high rejection rates. This is in line with the findings of e.g. Fischer et al. (2012) about the importance of values. Summarizing, psychographics are posing as an obstacle but also as chances to enhance the product acceptance of nanofood and -packaging.

General discussion & conclusion

Looking back to the research question, one can state that there are numerous obstacles to overcome to reach widespread product acceptance. Most of them are interlinked with risk/benefit perception referring to oneself, wider society and/ or the environment. Summing up, it is safe to say that risk/ benefit perception is the most influential factor which gets supported from literature from the relating field of GM food research (e.g. Rodríguez-Entrena et al., 2016). By means of this, especially perceived nanoparticle proximity is a big obstacle due to perceived health risks. Providing information and therefore increasing knowledge leads to mixed results due to psychological and demographic reasons. Psychological barriers are manifold and present themselves in lack of trust and general neophobia related to traditionalism/ conservatism. Trust is a major factor for all kinds of food novelties (Eiser et al., 2002) so this finding is rather uncontroversial. Further intermingling with trust are factors like stakeholder engagement (SE) and institutional and regulatory uncertainties which are also prominent obstacles. Values play an important role regarding those factors. If they are perceived as shared, one is more likely to trust the information given by the "sender". Hence there is higher acceptance of nanofood and -packaging. The issue of conservatism/ traditionalism applies especially to the demographic group of older consumers. So, the older the consumer segment, the lower the acceptance rate. Next to that, geographic variables play an important role which has been explained by different cultures and therefore traditions. This was found to be true for developed and developing countries. Aligning with that, it was found that in developing countries nanofood was more accepted than nanopackgaing. The reverse revealed for developed countries. Another general trend is that female consumers are rejecting nanotechnology in the food sector more often than men. The same applies to people having lower socio-economic status (income and education). As discussed before, socio-economic status might be the key to explaining another main finding: White males tend to be the most accepting towards nanotechnology in the food sector. The causal chain of affect leading to a negative evaluation of information and therefore heightened perceived risks is supported by a majority of researchers with an unclear role of trust since it is not mentioned by all researchers. This means affect is an important factor for product acceptance. Additionally, price is a big obstacle for most consumers even for the ones in the higher income classes. But there is some evidence that brand may outweigh the price factor (Schnettler et al, 2013a). What's more is that the linked concepts attitude towards GM food and preference for healthy/ and organic food both are hurdles for a widespread acceptance of nanotechnology in the food sector. This has to do with both the risk perception as well as with traditionalism and conservatism. Still, the GM food's public image spillover is prevented mostly by lack of knowledge about nanotechnology.

Regarding this research, it is not clear in how far the researchers influenced each other like in the case with the consensus regarding the affect-risk/benefit causal chain. This is especially critical when seeing that there is no empirical evidence provided and there is a follow up study from an "outside" author (Öner et al., 2013) disputing the original causal chain. Apart from this opposing author, Siegrist himself modified the affect-acceptance casual chain in his research about the acceptance of GM food in 2011 (Connor & Siegrist, 2011). Also, in most cases, the first author and co-authors are working together quite frequently as can be seen with Siegrist et al. (2007) and Stampfli et al. (2010). This might be due to the field of research being quite new and therefore exchange between the relatively few researchers being quite easy and frequent. The same can be observed with e.g. Frewer and Fischer who appear both as main or co-authors in numerous that were included. Since Fischer was the supervisor of this review, this possibly steered the research to psychology related search terms leaving some sociological results out. In general, the choice of search terms bears the possibility of leaving out results. A frequent contributor that stands out is Schnettler because she is not constantly involved in publication of other authors. That might also be due to another demographic and big cultural and geographic distance. When considering this, it comes as no surprise that literature reviews tend to yield similar results. Some studies had a rather small sample size due to them being interviews, experiments or literature reviews (Yawson & Kuzma, 2010; Frewer et al., 2011; Roosen et al., 2014). Others were just having a small survey sample size like Siegrist et al. (2007). Furthermore, some papers openly state having had convenience samples (Siegrist et al. 2007; Öner et al., 2013; Lopéz-Vázquez et al., 2012). This of course influences the outcomes for demographics especially for the factor education. However, most others authors from developing countries used a random sample such as Vidigal et al. (2015) and Schnettler et al. (2013a, 2013b, 2014). So the outcomes for the differences between the developed and developing countries remain valid. Additionally, factors such as "confidence" (cf. Brown et al., 2015, p. 2) and "transparency" (Ueland et al., 2012, p.7) which are closely related to trust were not especially looked for. But since synonyms were incorporated as well, this is a minor and predictable limitation. The codes applied revealed the frequency but this does not necessarily to the factors importance. Further research can therefore emphasize on single factor impact.

Certain people were found to be rejecting nanotechnology in the food sector more often than others. Amongst them old people, women and those of comparably low socio-economic status. According to that, the people most likely to accept nanotechnology in the food sector are young, highly educated men. They see benefits due to functionality whereas e.g. older women oppose it for the same reason or simply because it is new. On the one hand, one can expect this to change since nowadays more women and wider parts of society get college education. But on the other hand, one tries to reach

acceptance in the recent groups as well. This research focused mainly on psychological variables of product acceptance. So, it would be interesting to investigate if this elite group will actually act as "opinion leaders" and other groups follow their example. Thus, a more sociologically-framed follow-up research into this topic promises to yield interesting results on how to lower rejection rates in hard to convince groups. This research delivered mixed results regarding religiousness. This aligns with for example Vandermoere et al. (2010) significant research which found no correlation between religiousness and acceptance despite authors like Scheufele et al. (2009) claiming it is a major obstacle.

Concluding from all of this, it is of major importance to lower risk and therefore heighten benefit perception. Since simply enhancing information, familiarity and awareness is not helping to reach this goal, positive affect should be sought. To start with, trust is important because it will lead to higher perceived stakeholder engagement and institutional and regulatory certainty. It should be mentioned here that this is hard to achieve and a long-term process. When considering this, it should be kept in mind that some authors like e.g. Poortinga & Pidgeon (2004) argue that perceived trust is easier to be destroyed and achieved. So, the question is if it is worth to focus on that when trying to reach product acceptance. But the literature findings suggest that to achieve positive affect and trust marketers can use the leverage of perceived similar values. Ways to increase trust or to rather prevent distrust should hence be researched more intensively. Also, future research could focus on finding out about how to frame nanofood and -packaging as less interfering with tradition. The more promising alternative to that is to emphasizing the socializing effect of food through for example a better tasting product. Besides that, there needs to be more research on obstacles leading females to reject nanotechnology in the food sector more often. This aligns with what was written about the need for a more sociology-based approach. A reason for that is that there are numerous publication pointing out that women are less open towards new technologies but there is controversy on societies influence on that. Hence, a research scrutinizing the difference between higher and lower educated women regarding product acceptance of nanotechnology in the food sector is promising. Since (high) price forms major obstacle, ways must be found to be able to stay in a price range with similar products without nanotechnology. A second option here would be to highlight benefits so that it seems worth buying nanofood or -packaging. Since the momentary perception is that risks outweigh benefits, this would require extra effort since wide market acceptance is not reached as of now. Another major goal is to prevent a spillover of the negative attitude towards GM food and satisfy the demand for food being perceived as healthy and natural. Here it is again important to highlight the potential health benefits of nanofood and -packaging. Also, one can argue that nanoparticles are appearing naturally anyways. This will be easier for nanopackaging because of

lower perceived proximity. Because proximity is seen as a major risk more emphasis has to be placed on consumer safety. Besides that, the affect-acceptance causal chain should be tested in an experimental setting to be either revised, strengthened or overhauled. This means it should be scrutinized whether this causal chain needs a different starting point or is not valid and an associative network instead.

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