A systematic review of consumer perceptions of smart packaging technologies for food

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Supplementary Tables

Table S1: Included Studies

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| **Paper & Method** | **Aim. To Identify:** | **Location & Technology** | **Major Conclusions** |
| Aday and Yener (2015)Survey (n=365) ; TF: NA | How consumers are approaching new packaging; which concepts they would prefer/reject; and how to increase the acceptability of AP&IP | TurkeyAP&IP (general) | Consumers prefer IP to AP technologies. Consumers wanted to use AP to prevent microbial spoilage however sachets were considered potentially hazardous. Effective commercials and info campaigns about the new technology on labels can be helpful to increase public acceptance. |
| Barska and Wyrwa (2016)Survey (n=372); TF: NA | What consumers know/feel about AI&IP; determinants, directions of changes and trends | PolandAP&IP (general) | Level of knowledge about AI&IP is insufficient. Majority of consumers declare willingness to purchase food in AI&IP, and accept the need to pay higher price. |
| Daoud and Trigui (2019)Interviews (n=15); TF: NA | Factors influencing consumer perceptions of traceability information and the role of smart packaging in that. | TunisiaIP (provision of traceability features) | A conceptual model was developed linking knowledge of food technology and traceability, credibility, and food involvement to consumer perceptions of smart packaging and traceability information. |
| Erdem (2015)Survey (n=449); TF: Random Utility Theory | Preferences towards nano; equivalent risk reduction delivered with conventional technology | UKNano (intelligent-sensor detecting unacceptable level of food poisoning bacteria in chicken) | Consumers prefer chicken with lower risk of food poisoning, better animal welfare and lower costs, regardless of presence of nanosensors. When compared with conventional consumers, those who buy chicken with better animal welfare show higher WTP for food risk reduction. Higher standard deviation for WTP in nano group suggesting lack of knowledge, confusion or lack of trust. No strong evidence of positive preference towards nano. |
| Greehy, McCarthy, Henchion, Dillon, and McCarthy (2011)Deliberate Discourse Interviews (n=7); TF: NA | How consumers’ perceptions of risks/benefits of nano, their subjective values, and info/engagement can affect acceptance/rejection | IrelandNano (intelligent sensors to detect bacteria and food deterioration, active anti-microbial) | Participants unfamiliar with nano in food production. More accepting when perceive personal and societal benefits outweigh potential risks.Personal and societal health benefits, taste, perceived naturalness, price and shelf life framed consumers’ attitudes and overall acceptance. Acceptance was conditional on risks being addressed. If risk communication is to ensure acceptance, it should focus on benefits without ignoring risks. |
| Gupta, Fischer, and Frewer (2015)Structured Interviews (n=18); TF: NA | Types of concerns and priorities consumers have about different applications of nano; Alignment between consumer and expert concerns | UKNano (active anti-microbial) | Participants unfamiliar with nano and its applications. Participants differentiated between applications based on need, benefit, usefulness and importance, and were positive about packaging applications. Experts had perceived food/packaging applications will be less acceptable, but consumers perceived nano to be beneficial. Experts also failed to anticipate consumer concern for moral, social and ethical risks. |
| Henchion, McCarthy, Dillon, Greehy, and McCarthy (2019)Survey (n=1046); TF: NA | Consumer perceptions of two potential nano-inside and two nano-outside product applications | IrelandNano (active anti-microbial and intelligent chicken spoilage sensor) | Consumer acceptance and willingness to eat decreased when nano introduced. Nano-outside (packaging) applications have higher level of acceptance than nano-inside applications. Negative value of nano-packaging applications is offset by benefits (e.g. improved food safety). |
| Katare, Yue, and Hurley (2016)Auctions, Eye Tracking (n=109); TF: NA | How nano designed to enhance shelf-life affects consumer WTP, esp. how WTP differs across products with varying shelf-lives | USANano (active antimicrobial) | Probability of positive WTP and magnitude thereof is influenced by info provided. Participants with prior knowledge were less influenced by the info presented. WTP for nano is affected by education, income, household, age and gender. |
| Lindqvist et al. (2012)Focus groups (n= 4); TF: Value Driven Model | Which services interested the consumer, what tied the consumer to the brand, opinions on the technology suitability to cases, functionality, and obstacles to use | Finland (presumed)IP (automatic info provision including traceability) | Consumers are often in a hurry so info provision should only work on request. Users suggested a variety of info would be useful including origin of components (traceability). Obstacles for use included time constraints, data costs to download info, compatibility between apps and mobile device. |
| López-Vázquez, Brunner, and Siegrist (2012)Survey (n=378); TF: Siegrist et al Model | How laypeople arrange their perceptions of nanotechnology foods and packaging after existing and potential applications are described in brief summaries | MexicoNano (active oxygen scavenging and antimicrobial) | Packaging was seen to be a low control application, and perceived control acts as an important factor that influences risk perception. Negative perceptions are strongly related to perceived risk and perceived benefit. |
| Loučanová, Kalamárová, Parobek, and Dopico (2016)Survey (n=120); TF: Kano Model | Differences between customers’ perceptions of AP&IP functions | SlovakiaAP&IP (general) | Attitudes to AP&IP vary according to age. Most significant value was for consumers in the 41-50 year age range. Over 41 years of age, AP is more attractive. Less than 40 years of age IP is more attractive. Aligns with prioritization of packaging functions. |
| Loučanová, Kalamárová, and Parobek (2017)Survey (n=120); TF: Kano Model | The age categories which are most interested in packaging innovation | SlovakiaAP&IP (general) | Main group to target AI&IP to is the 41-50 year age group. 41+ suggest AP focus, younger an IP focus. Recommendation to companies to consider age range target for products and utilize AP &IP accordingly. |
| Loučanová, Nosálová, Parobek, and Dopico (2018)Survey (n=767); TF: Kano Model | The awareness and attitudes of intelligent and AP | SlovakiaAP&IP (general) | Low levels of awareness of AP&IP. Consumers cannot identify and therefore do not positively evaluate benefits. By increasing awareness, consumers have the ability to evaluate the positives better and then AP&IP have the potential to represent a competitive advantage. |
| Loučanová, Nosáľová, and Olšiaková (2019)Survey (n=937); TF: Kano Model | How acceptance of AP&IP changes over time | SlovakiaAP&IP (general) | Positive shift in opinions on AP&IP by Slovak consumers. Younger consumers evaluate the functionality of AP&IP as an added value. |
| Loučanová, Parobek, Nosáľová, and Dopico (2019)Survey (n=552); TF: Kano Model | Perceptions of IP as ecological innovations | SlovakiaAP&IP (general) | Awareness of IP is low and thus consumers cannot positively evaluate their features making them a weak green strategy. |
| Matin et al. (2012)Survey (n=777); TF: Food Technology Neophobia | Relationships between environmental and human beliefs and people’s fear of novel (nano) technologies | CanadaNano (active antimicrobial and intelligent nano-biosensors) | Levels of food neophobia is significant in explaining opposition to nanotechnology.There’s a low probability of trade-offs between environmental concerns and acceptance of new technologies. Consumers with the high environmental focus do not support use of nanotechnology. |
| Nosálová, Loučanová, and Parobek (2018)Survey (n=200); TF: NA | Preferential packaging functions in active and IP by “Millennial Generation” consumers | SlovakiaAP&IP (general) | Awareness is low for AI&IP. The characterized importance of the protective function was reflected in an interest for AP. AI&IP have the potential to represent a competitive advantage. |
| O' Callaghan and Kerry (2016)Survey (n=814); TF: NA | Opinions on the shelf life from current cheese packaging and assess knowledge and attitudes towards novel technologies that extend shelf like or communicate info on quality, with particular focus on WTP if price increased | GlobalAP&IP (applied to cheese products) | The provision of info on the technologies used to achieve shelf life extension may positively influence purchasing decision. 18-34 year old consumers were more like to accept a cost increase. Attitudes towards smart packaging are mainly positive for applications in fast moving consumer goods like cheese. However some questioned the appropriateness of AP for cheese as it seemed redundant/unnecessary. |
| Öner, Karaca, Beşer, and Yildirmaz (2013)Survey (n=324); TF: Siegrist et al Model | The applicability of the model on acceptance of nano in a different cultural context; Data differences with Switzerland; A set of assessment tools for further studies | TurkeyNano (general) | Social trust appears linked to risk perception. There is no relationship between affect and willingness to buy, or social trust to willingness to buy. There is a significant and negative relationship between risk and willingness to buy that is not significant in Siegrist et al (2007). No evidence for nano-inside applications being less acceptable than nano-outside applications. |
| Pennanen et al. (2015)Focus groups (n=16) and Survey (n=2525); TF: NA | The factors affecting consumers’ interest in TTIs | Finland, Germany, Greece, FranceIP (TTIs) | Consumers could recognize numerous benefits and challenges with TTI implementation, and saw value in the benefits. |
| Schnettler et al. (2014)Survey (n=400); TF: Siegrist et al Model | Acceptance of nano, consumer segments in terms of their preferences and characterize according to knowledge, socio-demographics and level of satisfaction with food related life | ChileNano (active antimicrobial) | Brand was the attribute of most importance to consumers, followed by the type of nano application in the packaging. 3 segments identified (2nd and 3rd preferred oil with nano but differed in the types of technology applications). Nano should be endorsed by well-known brands. |
| Sodano, Gorgitano, Verneau, and Vitale (2016)Survey (n=~300); TF: Willingness to Buy Model (developed) | Consumers’ attitudes towards a set of nano applications | ItalyNano (active antimicrobial) | Some reluctance to buy foods utilizing nano due to risk perception higher than expected benefits, low levels of trust and food technophobia. Consumer reluctance is suggested to demand a more transparent and responsible introduction of new technologies. Policy makers should intervene to address risks involved in new technologies rather than engaging in communication aimed at increasing public acceptance. |
| Spence, Stancu, Elliott, and Dean (2018)Survey (n=616); TF: Extended Theory of Planned Behavior | The applicability of the model by measuring attitudes to traceable (versus conventional) meat products | EnglandIP (providing traceability for meat products) | Consumers had a general favorable attitude with positive behavioral beliefs and high trust towards traceable beef. In the Theory of Planned Behavior model, attitude was the main determinant for intention to purchase followed by subjective norm and perceived behavior control. |
| Stampfli, Siegrist, and Kastenholz (2010)Survey (n=514); TF: Willingness to Buy Model (developed) | The influence of risk info on the acceptance of nanotechnology food and food packaging | SwitzerlandNano (active decay inhibiting and antimicrobial) | Social trust had a significant effect on perceived risks and benefits. Preference for healthy food significantly correlated with perceived risk but not perceived benefit. Perceived benefit explained a large part of the willingness to buy variance. Acceptance varied between applications with acceptance higher for non-ingested applications. |
| Vandermoere, Blanchemanche, Bieberstein, Marette, and Roosen (2011)Survey (n=752); TF: NA | Perceptions of specific food/food packaging applications, and whether there is a difference in acceptance between nano-inside and nano-outside applications and determinants for these perceptions | FranceNano (active antimicrobial and intelligent nano-biosensors) | Majority of consumers are not familiar with nano and both men and women are ambiguous about nano-food packaging. Increasing people’s knowledge may not be sufficient to bridge gap between industry enthusiasm and consumers’ restraint so research needs to pay more attention to participation rather than risk communication. Measures to increase trust in the supply chain is suggested to lead to higher acceptance. |
| Van Wezemael, Ueland, and Verbeke (2011)Survey (n=2520) ; TF: NA | Consumers’ responses to different beef packaging technologies with particular emphasis on safety aspects of the packaging | France, Germany, Poland, Spain, UKNano (active antimicrobial, beef) | Familiarity is a major determinant of acceptance of beef packaging technologies. AP was highly rejected compared with the other packaging technologies, with more than 1/3 of participants deeming the technology unacceptable, although 30% did consider the AP acceptable. The phrasing in communication of the AP technologies influences consumer acceptance. |
| Wilson, Harte, and Almenar (2018)Survey (n=94); TF: NA | Consumer attitudes and perceptions towards AP, esp. if visible sachet in affects acceptance | USAAP (sachet format for cut cantaloupe) | Consumers like packages with sachets less than the packages without. AP that incorporates compounds by means other than visible sachets may see greater acceptance, particularly if the AP extends shelf life. |
| Zhou and Hu (2018)Survey (n=1131); TF: Random Utility/Mixed Logit Model | Public perceptions of nanotechnology in food and food related products | USANano (intelligent nano quality sensors) | Consumers were (on average) indifferent to the nano, with the WTP insignificant from zero. |

*Abbreviations: TF=Theoretical Framework; WTP= Willingness to Pay; AP=Active Packaging; IP=Intelligent Packaging; Nano= Food Packaging Nanotechnology; TTI=Time Temperature Indicator*