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Research report

Food nanotechnology in the news. Coverage patterns and thematic emphases during the last decade☆

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ABSTRACT

For novel issues like food nanotechnology, media can play an important role in shaping the awareness and mental associations that underlie public opinion. Seeking to complement recent research exploring public opinion formation about food nanotechnology, this study tracks the evolution of U.S. newspaper coverage of food nanotechnology, identifying the descriptive and thematic traits that have characterized this coverage over time. We use a rigorous methodology to examine the levels of coverage, authorship patterns, and thematic emphases exhibited in the American journalistic narrative about this burgeoning application of nanoscience. Our findings indicate that U.S. newspaper coverage of food nanotechnology is relatively modest in terms of how often it has been covered, its thematic diversity, and the level of journalistic expertise from which it was produced. To our knowledge, this is the first study to empirically assess journalistic coverage of food nanotechnology.

1. Introduction

Despite the rapid pace of investment and scientific innovation in food nanotechnology (Kuzma & VerHage, 2006), its marketplace success will likely be influenced by mediated (mis)information (see, for example, Shelton & Roush, 1999) and the extent to which it is embraced by consumers (Chaudhry et al., 2008; MacFie, 2007). Much ambiguity, however, currently enshrouds the issue of food nanotechnology. The recent two-volume report, Nanotechnologies and Food, by the Science and Technology Committee of the U.K. House of Lords finds that scant attention has been devoted to the application of nanoscience to the food sector, and advocates the pressing need for serious research into its implications––both scientific and social (House of Lords, 2010). Moreover, the House of Lords report makes clear the potential for public backlash given certain similarities between food nanotechnologies and GMOs:

> Consumers are particularly sensitive about new technologies involving the scientific manipulation of food and understandably cautious about their introduction. The public response to the development of genetically modified food illustrates how quickly the views of some sectors of the public can change if action is not taken to meet concerns they may have about a new food technology (p. 8).

It is of particular import that the public opinion climate surrounding food nanotechnology be considered upstream, during the initial stages of product development (Siegrist, 2008). Doing so requires that we investigate how the public becomes aware of a novel and potentially controversial issue like food nanotechnology. And, if we want food nanotechnology to develop in ways that acknowledge societal considerations––a key objective of the 2007 National Nanotechnology Initiative strategic plan (National Nanotechnology Initiative, 2007)––we must also investigate, at minimum, how the public acquires baseline information about this issue that can be used to help form judgments and perceptions.

Addressing these issues requires a systematic, longitudinal assessment of how media depict the issue of food nanotechnology. This is particularly important for emerging issues, such as food nanotechnology, that lay publics are largely unfamiliar with and where media can therefore play an important role in creating the awareness and mental associations that ultimately shape policy decisions (e.g., Scheufele, 2006).

With these considerations in mind, we track the evolution of U.S. newspaper coverage of food nanotechnology. Using a

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comprehensive sampling technique and analysis, we identify the coverage trends, authorship patterns, and thematic emphases that have characterized journalistic accounts of this issue over the last decade. By unearthing the dominant traits of this coverage we generate knowledge that enhances our ability to understand and anticipate public perceptions regarding food nanotechnology.

1.1. Food nanotechnology

To understand the issue of food nanotechnology it is first necessary to understand nanotechnology. The term "nanotechnology" refers to a broad area of technological activity focused on the engineering and manipulation of objects at the nanoscale, up to 100 nanometers in size. Nanoscience is a multidisciplinary endeavor (Wood, Jones, & Geldart, 2007) that, like many emerging technologies that have come before it, enables the creation of applications that often pose significant ethical, legal, and social implications (ELSIs). Despite the complexities raised by these ELSIs, nanotechnology research and development is very well funded (for details, see, National Nanotechnology Initiative, 2008) and continues apace. And although estimates vary (Berube, Searson, Morton, & Cummings, 2010), nanotechnology is already present in more than 1000 consumer end products in the U.S., from tennis rackets to dress pants to cleaning fluids (Scheufele & Dudo, 2010).

Nanotechnology offers much promise to food science (Sanguansri & Augustin, 2006). "Food nanotechnology," simply, refers to the application of nanoscience to the food sector. More specifically, in this study we conceptualize food nanotechnology as novel breakthroughs and application developments made possible by nano-level science and engineering applied to the "structure, texture, and quality of foodstuffs" and food-related products (Chaudhry et al., 2008, p. 241). Food nanotechnology includes a range of potential applications, including alterations to the properties of foods (e.g., nano-additives and nano-ingredients); improvements to the delivery, quality, and safety of food; and the development of enhanced food packaging (i.e., food contact materials) (Buzby, 2010). For example, scientists are creating food packages that contain nano-sized particles devised to warn consumers that a food product is unsafe to eat, and are inventing nanoencapsulated materials that can distribute nutrients to human cells (Kuzma & VerHage, 2006).

The food industry has been researching how nanoscience can be used to improve food since 1999 (House of Lords, 2010), and there are signs that the research and development of food nanotechnologies is likely to grow quickly in the coming years (Chaudhry et al., 2008). Significant financial investments are being made in food nanotechnology (Berube, 2006; Kuzma & VerHage, 2006), though economic projections are unclear. For example, one report estimates that the value of food nanotechnology products worldwide will reach 5.8 billion USD by 2012 (Cientifica, 2007, as cited in House of Lords, 2010), while another report predicts the overall food nanotechnology market will surge to 20.4 billion (USD) in 2010 (Helmuth Kaiser Consultancy, 2004, as cited in Joseph & Morrison, 2006). Further, in 2008 nano-derived packaging for food and beverages was valued at $4.2 billion and projected to increase to more than $7 billion by 2014 (Brody, 2010). It is also unclear how many food-related nanotechnology products are currently available in the marketplace. The Project on Emerging Nanotechnologies maintains an inventory of consumer products with nanotechnology, which currently includes 98 in its "food and beverage" category (Maynard & Michelson, 2006). This inventory, however, likely underestimates the number of consumer products in the marketplace (Chun, 2009), and it is probable the number will grow rapidly within the next five years (House of Lords, 2010).

1.2. Food nanotechnology applications and potential benefits

Nanotechnology is expected to influence numerous areas of food science in ways that will benefit both the food industry and consumers (Kuzma & VerHage, 2006). For example, nanotechnology is being used to improve the quality and safety of food. Nano-derived innovations to food packaging are being designed to enhance food safety and help reduce food waste (Arora & Padua, 2010; Berube, 2006; Brody, 2010; Chaudhry et al., 2008; Chun, 2009; House of Lords, 2010; Siegrist, Stampfli, Kastenholz, & Keller, 2008; Sorrentino, Gorrasi, & Vittoria, 2007). Nano sensors are being developed that can detect and signal the presence of spoilage microorganisms, and potentially even differentiate the presence of pathogenic from benign microorganisms (Brody, 2010). Nanotechnology is also being used to create healthier foods (House of Lords, 2010; Jandt, 2006; Weiss, Takhistov, & McClements, 2006) that can deliver nutrients and medications to different parts of the human body (Berube, 2006; Chun, 2009) and can alleviate allergenic properties (Wogan, 2010). And nanotechnology is also likely to enable substantial benefits to food manufacturing (House of Lords, 2010) and agricultural production. Nanomaterials, for instance, might be developed to improve the delivery of nutrients and pesticides to crops (Berube, 2006; Robinson & Morrison, 2009), which some experts speculate could help developing countries (Chun, 2009; Salamanca-Buentello et al., 2005).

1.3. Potential risks of food nanotechnology

But with these potential benefits come potential risks (Pusztai & Bardocz, 2006; Siegrist et al., 2008). On one hand, while nanoscale components already occur naturally in many foods (Chun, 2009), food nanotechnologies may pose direct risks to human health. Recent research shows that inhaled nanoparticles can accumulate in the lungs and cause chronic diseases due to their small scale (Chau, Wu, & Yen, 2007; also see, Poland et al., 2008). This research, however, has focused on risks associated with the inhalation of nanoparticles and not risks associated with their direct ingestion through the gastrointestinal (GI) route, for which the effects are "largely unknown" (Chaudhry et al., 2008, p. 248; House of Lords, 2010; Siegrist et al., 2008). Discussions of these direct risks often center on the issue of bioavailability; the phenomenon whereby nanoparticles more readily bypass cellular barriers in the body that are impenetrable to regular foods, then spread and accumulate in other areas of the body with unknown long-term effects (Chun, 2009; Wogan, 2010). This potential increased bioavailability could pose numerous risks to the human body, including changes to the nutrient profile, greater absorption of nano-additives, and the introduction of foreign substances into the blood (Buzby, 2010; Chaudhry et al., 2008).

Food-related nanotechnologies may also pose indirect threats to human health. For example, food could be contaminated by the use of nano-sized pesticides and nanoparticles could migrate into food from nano-packaging (Chaudhry et al., 2008). There is also the possibility that nanoparticles could bioconcentrate in the environment and alter the food chain (Buzby, 2010; Chaudhry et al., 2008). Yet little research has examined these potential outcomes and current regulatory frameworks seem ill equipped to successfully mitigate these possible risks––both direct and indirect (Chaudhry et al., 2008). Buzby (2010) notes numerous deficits in the current regulatory system for nanotechnology, including an inability in U.S. laws and regulations to handle the growth of nanotechnology in commercial applications, and an unclear plan for the future oversight of nanotechnology, particularly which U.S. agency or agencies should have these oversight responsibilities. What is more, there is also growing concern that the food industry is being

taciturn when it comes to possible health and safety outcomes of nano-related foods (House of Lords, 2010).

The uncertainty––and suspected secrecy––that characterize these potential risks and regulatory issues make food nanotechnology, like agricultural biotechnology before it, particularly controversial with respect to public health and place it in a potentially volatile position when it comes to public opinion. While it may still be too soon to predict the impact nanotechnology will have on food (Chun, 2009), the success of food nanotechnology will hinge on how the tradeoffs between its benefits, risks, and uncertainties influence public acceptance.

1.4. Public perceptions

Much of the research examining public opinion has focused on nanotechnology in general and not on its specific applications. For example, surveys have shown that the public is largely unaware of nanotechnology (Cobb & Macoubrie, 2004; Peter D. Hart Research Associates, 2007), and that levels of actual knowledge about nanotechnology––both in the U.S. and Europe––continue to be low (Cobb & Macoubrie, 2004; Lee, Scheufele, & Lewenstein, 2005; Scheufele, Corley, Shih, Dalrymple, & Ho, 2009). Moreover, there is evidence of a growing nanotechnology-related knowledge gap. A comparison of two U.S. surveys from 2004 (Scheufele & Lewenstein, 2005) and 2007 (Scheufele et al., 2007) shows increases in nanotechnology knowledge for highly educated respondents and decreases in nanotechnology knowledge for the least educated respondents (Corley & Scheufele, 2010). Surveys have also examined public perceptions of nanotechnology, finding, for example, that the U.S. public perceives fewer potential benefits and, in most cases, more risks from nanotechnology than U.S. scientists (Scheufele et al., 2007), and that the U.S. public is more optimistic toward nanotechnology that the European public (Gaskell, Ten Eyck, Jackson, & Veltri, 2005).

A handful of recent studies by Siegrist and colleagues have examined potential public responses to food nanotechnology. Their research highlights factors that are likely to influence public acceptance of food-related nanotechnologies. For example, their results suggest that individuals are more likely to accept food nanotechnologies when they have higher levels of trust in the food industry (Siegrist, Cousin, Kastenholz, & Wiek, 2007; Siegrist, 2008; Siegrist et al., 2008) and perceive higher levels of naturalness in the nanotechnology food products (Siegrist, 2008; Siegrist et al., 2008; Siegrist, Stampfli, & Kastenholz, 2009). Conversely, their results suggest that individuals are less likely to accept food nanotechnologies when they have higher levels of negative affect and perceive lower levels of control regarding food nanotechnologies (Siegrist et al., 2008). Their work has also shown that individuals' perceived benefits and risks influence their degree of acceptance (Siegrist, 2008), and that nano-derived food packaging is perceived of as more beneficial than nano-derived foods (Siegrist et al., 2007, 2008).

This research offers valuable insight into potential public perceptions of food nanotechnology. But this research also begs one question: From where do these perceptions originate? In other words, what is it that enables members of the public to become aware and form perceptions––good or bad, informed or not informed––about food nanotechnology, especially considering how little the public knows about nanotechnology, let alone how nanoscience is being applied to food? Media represent an important source of these perceptions.

1.5. Media influence

How individuals come to understand and perceive scientific issues is complex, but decades of research show that the media is the public's primary source of information about science and technology (e.g., Allan, 2002; Friedman, Dunwoody, & Rogers, 1986; Gregory & Miller, 1998; National Science Board, 2008, 2010). Theoretical frameworks from the social sciences help explain how media can contribute to public awareness, knowledge, and perception regarding technoscientific issues. One role of mediated messages is that of notifying audiences to new and noteworthy events. In this capacity, the media help audiences observe relevant social issues (McLeod & Becker, 1974). This monitoring function forms the conceptual foundation of the agenda-setting effect, which posits that exposure to mediated messages about an issue can increase the perceived importance of that issue among audience members (McCombs, 2004).

In addition to increasing audience awareness of scientific issues, media also influence the formation of perceptions. The concept of priming––commonly considered an extension of agenda setting (Scheufele & Tewksbury, 2007)––is based on the idea that frequent coverage in news media can make aspects of issues more easily accessible (i.e., more easily recalled) in people's minds, thereby making it more likely that these aspects will form the foundation of individuals' evaluative processes (Krosnick & Kinder, 1990; Zaller, 1991). In other words, the increased accessibility of issues led by frequent coverage in news media plays a role as a heuristic cue when individuals make decision about the issues (Iyengar & Kinder, 1987). In the context of scientific issues in the media, priming might occur when media messages imply that certain "benchmarks" be considered when forming related perceptions (Scheufele & Tewksbury, 2007, p. 11).

Framing also helps explain media contributions to public perceptions of scientific issues. Unlike agenda setting and priming, which help explain how media influence levels of awareness and accessibility, framing addresses how media presentations influence individuals' interpretation of issues (Tewksbury & Scheufele, 2009). Framing assumes that acute differences in media messages (e.g., terminology, narrative structures, imagery, etc.) can result in distinct interpretations of the same information among audience members (Scheufele, 1999). For example, two news reports containing similar information about food nanotechnology may present the information dissimilarly, in ways that resonate differently with individuals' interpretive schemas (Shoemaker & Reese, 1996). In this case, the disparate message frames could lead people to connect food nanotechnology with different concepts, say lucrative investment opportunities on one hand, or potentially severe human health risks on the other.

These media effects––agenda setting, priming, and framing––are most likely when an issue is novel. This is the point at which individuals do not yet have existing interpretive schema to represent the issue, and is when one would expect individuals to use media representations to begin to formulate their initial awareness and perceptions. Now is the time when careful analyses of media coverage of food nanotechnology––still a novel issue in the public domain––can be most informative to our attempts to understand the public opinion dynamics that will come to characterize this burgeoning issue.

1.6. Media coverage of nanotechnology

Numerous empirical analyses of nanotechnology-related media coverage have been conducted within the previous five years, despite the technology's relatively low level of public visibility. Similar to the body of research examining public perceptions, this work has focused on nanotechnology in a broad sense and not on specific applications. The results of these studies, however, are still informative for our analysis of food nanotechnology in U.S. newspapers.

Some relatively strong patterns seem to characterize the demographic aspects of nanotechnology media coverage. For

example, the volume of media coverage of nanotechnology has been relatively modest over time (Arias, 2004; Dudo, Dunwoody, & Scheufele, in press; Friedman & Egolf, 2005; Gorss & Lewenstein, 2005; Laing, 2005; te Kulve, 2006; Weaver, Lively, & Bimber, 2009), has carried a positive tone (Arias, 2004; Gaskell et al., 2005; Gorss & Lewenstein, 2005; Kjærgaard, 2010; Laing, 2005; Stephens, 2005; Wilkinson, Allan, Anderson, & Petersen, 2007), and has been authored by a disproportionately small group of journalists (Dudo et al., in press).

Many of the content analyses also examined the thematic emphases present in the stories. While labels differ, making direct comparisons across the studies difficult, some of the thematic patterns unearthed include a preponderance of coverage focusing on 'scientific research' (Dudo et al., in press; Weaver et al., 2009) and 'business' (Dudo et al., in press). There is also evidence of some interesting thematic shifts. Recent content analyses (see, for example, Dudo et al., in press; Weaver et al., 2009) have noted increases in the presence of coverage discussing 'regulations' and 'health,' both themes that seem to have had minimal presence in the past (Anderson, Allan, Petersen, & Wilkinson, 2005; Friedman & Egolf, 2005; Wilkinson et al., 2007). And a previous focus on generic benefits of nanotechnology (Arias, 2004; Gaskell et al., 2005; Gorss & Lewenstein, 2005; Laing, 2005; Stephens, 2005; Wilkinson et al., 2007) is being challenged by an increased focus on the technology's generic risks (Dudo et al., in press; Weaver et al., 2009).

While many of these content studies examined U.S. newspaper coverage of nanotechnology, some have explored coverage in European countries. Analyses of nanotechnology reporting in U.K. newspapers suggest coverage that has contained a mix of optimism about the benefits of nanoscience and anxiety about its potential risks (Wilkinson et al., 2007), and that U.S. coverage, though mostly similar to U.K. coverage, tends to be more positive in tone overall (Friedman & Egolf, 2005; Gaskell et al., 2005). Similarly, it appears that news stories in the Netherlands and Denmark have predominantly covered the positive and beneficial aspects of nanotechnology (Kjærgaard, 2010; te Kulve, 2006).

Collectively, this research offers a relatively comprehensive sense of how media––both in the United States and in Europe––have covered nanotechnology since it came on the scene in the 1980s. With this knowledge in hand, it is now necessary for researchers to undertake more granular examinations of nanotechnology coverage, assessing how media depict specific applications of nanotechnology. We aim to contribute to this goal. To our knowledge, this study is the first empirical examination of the media treatment of food nanotechnology.

1.7. Research questions

Our examination of food nanotechnology newspaper coverage reflects the extant content analytic work on nanotechnology and focuses on amount of coverage, authorship patterns, and thematic emphases.

The most basic effect media can have on audiences is making them aware of emerging issues. As posited by the agenda-setting effect, news media coverage of an issue can increase the perceived importance of that issue among audience members. The amount of journalistic attention dedicated to food nanotechnology represents an important first step in the formation of public perception. As such, our first and most basic question addresses the sheer volume of newspaper stories about food nanotechnology. Since our sample covers a 30-year span––1980–2009––we can explore this question over nearly the entire existence of nanotechnology.

RQ1: How often do U.S. newspapers cover the issue of food nanotechnology?

It is likely that U.S. news media regard the food nanotechnology issue as being highly specialized and assign its coverage to science journalists and other specialist reporters. This might result in an "inner club" (Dunwoody, 1980) of select journalists who pen the lion's share of coverage of the topic. The recent changes to the media landscape––namely the decreasing number of science journalists (Mooney, 2008; Mooney & Kirshenbaum, 2009a) and the shrinking science-related news hole in U.S. newspapers (The Pew Research Center, 2008b)––may make this possibility all the more likely. However, it is also possible that the increasingly fragmented media could result in a larger group of journalists reporting on food nanotechnology. These authorship patterns could affect the reporting of food nanotechnology in terms of how much coverage it receives and in terms of the content.

RQ2: Which journalists are authoring newspaper stories about food nanotechnology?

As described above, numerous theoretical orientations provide explanations for how media can contribute to the formation of public perceptions. Priming, for example, asserts frequent coverage in news media can make aspects of issues more easily accessible (i.e., more easily recalled) in people's minds, thereby making it more likely that these aspects will form the foundation of individuals' evaluative processes (Krosnick & Kinder, 1990; Zaller, 1991). And framing shows how acute differences in the presentation of media messages can result in distinct interpretations of the same information among audience members (Scheufele, 1999). Both of these theoretical lenses are useful for content analyses of emerging technologies. For instance, within the context of this study, priming implies that initial perceptions of food nanotechnology are likely to be driven by the dimensions of food nanotechnology that populate media coverage most frequently.

We are interested in tracking the appearance of varied thematic dimensions over time in journalistic narratives about food nanotechnology. Based on the theoretical orientations discussed above, it is likely that fledgling public perceptions about food nanotechnology will be influenced by the dominant themes that populate media coverage.[1] These effects would be consistent with recent research that finds media effects on public opinion about nanotechnology, specifically that many of these effects come from news coverage that deals with nanotechnology as part of broader themes of coverage, such as potential health treatments or economic implications (Kahan et al., 2008; Kahan, Braman, Slovic, Gastil, & Cohen, 2009; Scheufele & Lewenstein, 2005).

We examine two types of themes––what we label "content themes" and "conceptual themes"––because public reports and overviews identify them as highly relevant dimensions of food nanotechnology (see, for example, ETC Group, 2004; House of Lords, 2010; Kuzma & VerHage, 2006; Sekhon, 2010; Tarver, 2006) and because of their traditional conceptual importance in science communication research (for example, see, Friedman, Dunwoody, & Rogers, 1999). Content themes represent the broader topical dimensions that connect food nanotechnology to society. As is further detailed in Section 2, we examine our sample for the presence of two sub-groups of content themes: "consumer" and "sector" themes. We also examine our sample for the presence of

[1] Many of the extant content analyses that attempt to track media narratives in nanotechnology coverage focus on the identification of themes. While some of these studies refer to these themes as frames, we do not consider our study to be a frame analysis. Similar to Dudo et al. (in press) our team adopts a strict definition of framing, believing that a frame is much more than a thematic label; in addition to capturing content and conceptual aspects, a frame guides the user to a specific meaning, with all the affective and nuanced dimensions that such a meaning conveys. Themes, we believe, set the stage for frames but are not frames themselves. However, by examining these thematic emphases we are actually doing what many others do when they label their content studies of nanotechnology "frame analyses."

Table 1
Description of the themes coded in the content analysis.

Themes	Root words
Content	
Consumer	
Quality/Safety	safe[a], quality[a], contaminate[a], bacteria[a], sick/ill[a], sensor[a], fresh[a], health[a]
Packaging	package[a], wrapper[a], storage[a], container[a], coating[a], barrier[a], plastic[a], film[a]
Consumption	ingest[a], digest, eat[a], drink[a], absorb[a], swallow[a], inhale[a], stomach
Sector	
Business	business[a], economy[a], market[a], industry[a], product[a], consumer[a], commercial[a], patent[a]
Agriculture	agriculture[a], animal[a], crop[a], farm[a], corn[a], soil[a], plant[a], fruit/vegetable[a]
Regulations	regulate[a], guideline[a], oversight/monitor[a], policy[a], standard[a], law[a], rule[a], FDA
Conceptual	
Risks	risk[a], hazard[a], danger[a], threat[a], harm[a], exposure[a], peril[a], adverse[a]
Benefits	benefit[a], breakthrough[a], promise[a], advantage[a], revolution[a], innovation[a], discovery[a], useful[a]
Uncertainty	uncertain[a], unclear, unknown, inconclusive[a], unintended, controversy[a], unsure, unpredictable[a]

[a] Denotes that multiple forms of the root word were coded. For example, data was collected for "safe," "safer," "safety", etc., then summed to represent the data for the word "safe*."

three "conceptual themes," which include risks, benefits, and uncertainty. Though the themes we examine are mutually exclusive, we expect that any given story can contain multiple themes.

RQ3: How does the presence of key thematic dimensions vary in newspaper coverage of food nanotechnology?

2. Methods

2.1. Sample

Our sampling procedure was designed to capture a representative sample of U.S. newspaper coverage of nanotechnology. The sample contained 21 U.S. daily newspapers obtained via the LexisNexis Academic database. These particular newspapers were strategically chosen so that the sample represented a range of circulation sizes, ownership strata, and geographic locations.[2] (See Appendix A for more details about these newspapers.)

LexisNexis was first used to identify stories about nanotechnology published in these 21 newspapers between January 1, 1980 and December 31, 2009. We created a complex Boolean search term that was designed to maximize the retrieval of nanotechnology-related stories while simultaneously limiting the number of false positives (i.e., news stories that contained tangential nanotechnology-related content, such as reports about Apple's iPod nano). (See Appendix B for the exact Boolean search term.) All of the news stories returned from the search were exported from LexisNexis and stored as text files. We then manually screened each story retrieved by the search term in an effort to identify and remove any remaining false positives. We used the combination of these two search procedures––the Boolean term and subsequent manual screening––in order to improve the validity of our overall sample. The result of this process was a final sample of 1971 stories about nanotechnology.

We then transferred the final sample to the database management program, Filemaker Pro 10, to create a sub-sample composed of the news stories about food nanotechnology. We extracted food nanotechnology-related coverage from the main sample appearing between 1980 and 2009. The extraction process resulted in 250 news articles about food nanotechnology. As is described more thoroughly in the results, our authorship- and theme-oriented analyses are based on the food nanotechnology articles published between 1999 and 2009 ($n = 206$).

2.2. Coding and analysis

The unit of analysis for this study was the individual word. We used Filemaker Pro 10 to provide counts of particular words that represented our themes of interest (described next). Our analyses examined the sample's descriptive features (e.g., number of published news stories per year and patterns of authorship) and the presence of nine themes (see Table 1). Each of these nine themes represented one of two thematic dimensions: "content" or "conceptual". The "content" themes represent the broader topical dimensions within which the issue of food nanotechnology is being discussed. In effect, the content themes are those that place food nanotechnology within a broader social context or link it to individuals. We examine six content themes: quality/safety, packaging, and food consumption (which, together, represent consumer-oriented content themes), and business, agriculture, and regulations (which, together, represent sector-oriented content themes). We also coded for the presence of three "conceptual" themes––risks, benefits, and uncertainty––because they represent what are traditionally important conceptual aspects of science journalism.

Each theme was composed of a set of eight root words. The consumer theme "packaging," for instance, consisted of the following root words: package, wrapper, storage, container, coating, barrier, plastic, and film. To maximize the validity of the root word choices (that is, to choose eight words that collectively provide valid representations of each theme) we used a rigorous, multi-stage word selection process.[3] To address our research questions dealing with the themes of coverage and to

[2] As of 2009, LexisNexis did not provide access to The Boston Globe, The Seattle Times, or The Sacramento Bee. To maintain our sampling strategy, we therefore added three new newspapers to our sample: The Philadelphia Inquirer, The Baltimore Sun, and The Oregonian. We chose these three particular newspapers because of their similarities in terms of three criteria: circulation size, whether or not they publish a science section, and whether or not they are the only newspaper in their respective cities. For example, The Philadelphia Inquirer was substituted for The Boston Globe because of the similarities they share in terms of their circulation size, inclusion of a science section, and amount of competition they face from local competing newspapers. With these same considerations, we replaced The Seattle Times with The Baltimore Sun and replaced The Sacramento Bee with The Oregonian.

[3] In the first stage of the word selection process two researchers separately created lists of words that represented each of the nine themes. Their common goal was to be as exhaustive as possible. Next, these lists were merged (to reduce overlap and enhance comprehensiveness) and shared with a group of 10 colleagues not involved with this study. These 10 individuals were asked to review the words, and their feedback was then used to refine the word lists, mostly by removing words perceived to be tangential to the themes of interest. In the final stage, the three authors referred to the most current iteration of the word lists and worked collectively to choose eight words that were most illustrative of each of the nine themes. We used the same number of root words for each conceptual category because it allowed us to conduct a conservative but sufficiently comprehensive and comparative analysis of how often these conceptual categories occurred in the sample.

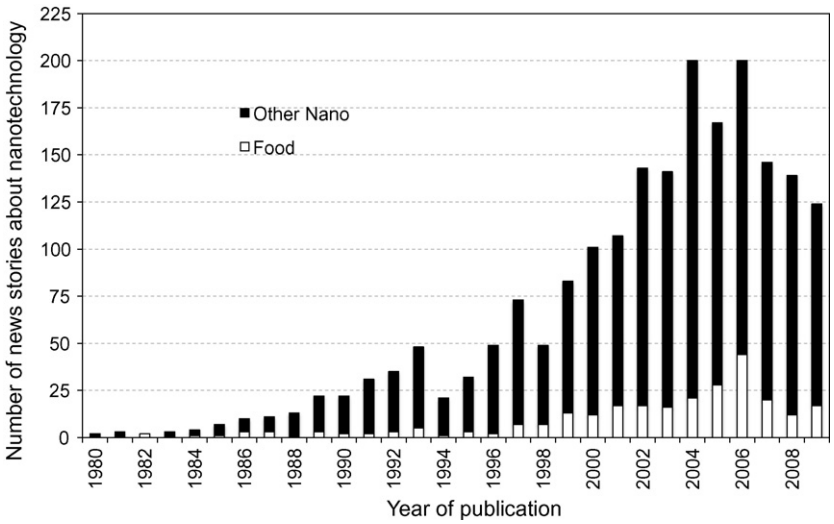

Fig. 1. Coverage of nanotechnology and food nanotechnology in U.S. newspapers.

control for variance in story numbers over time, we calculated the average number of mentions each theme received per news story in each year by calculating the average number of each theme's occurrence per newspaper story for each year relative to the number of newspaper stories published in each year. In essence, we controlled for the number of newspaper stories published each year so as to provide a more valid assessment of how often each theme appeared over time. We did not assess intercoder reliability because our use of computer-based analysis renders perfect reliability.

3. Results

3.1. Amount of coverage of food nanotechnology

Figure 1 depicts the amount of U.S. newspaper coverage about nanotechnology over the last three decades and the proportion of that coverage that was about food nanotechnology (RQ1). In general, the amount of nanotechnology coverage has been increasing consistently during this time, but has been decreasing slightly over the last three years. Coverage of food nanotechnology has mirrored this pattern, but on a delayed and much smaller scale. While newspaper coverage of nanotechnology began to emerge in the mid- to late-1980s, coverage about food nanotechnology did not start to appear (with relative frequency) until that late 1990s. Coverage of food nanotechnology experienced a steady increase from that point until its zenith in 2006 ($n = 44$), and, like general nanotechnology coverage, has decreased in the ensuing years. As shown below, the authorship- and theme-oriented analyses of food nanotechnology coverage (RQ3) extend from the beginning of 1999 to 2009, because 1999 was the first year more than 10 articles about this topic were published in the newspapers included in our sample.

Figure 2 provides further detail about the proportion of nanotechnology newspaper coverage that focused on food nanotechnology. Overall, it appears that coverage of food nanotechnology has accounted for approximately 15–20 percent of the overall coverage since 1999. This proportion has been quite stable, though there has been a slight uptick in the proportion in 2009 indicating a possible upward trend to come in ensuing years.

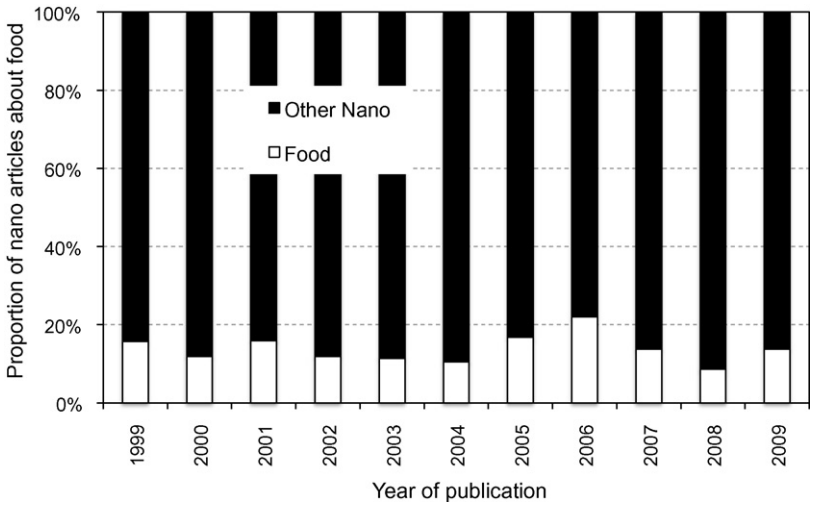

Fig. 2. Proportion of U.S. newspaper coverage of nanotechnology devoted to food nanotechnology since 1999.

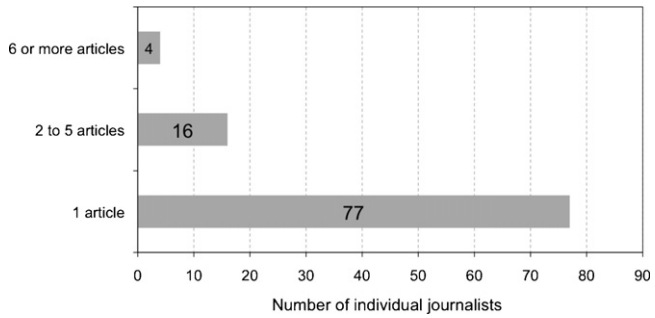

Fig. 3. Authorship frequency of newspaper stories about food nanotechnology.

Table 2
Journalists in our sample who have authored more than 6 articles about food nanotechnology[a].

Journalist	Newspaper affiliation	Number of articles
Barnaby J. Feder[b]	New York Times	13
Rick Weiss[b]	Washington Post	13
Henry Fountain	New York Times	11
Eric Berger	The Houston Chronicle	8

[a] This table reflects only the newspapers that were included in our sample and subsequent analyses, and is not an exhaustive list of all U.S. journalists who have written extensively about nanotechnology. This table is based on an analysis of news coverage about nanofood published between 1999 and 2009.
[b] These journalists are no longer working in the newspaper industry.

3.2. Authorship

RQ2 asks about authorship patterns in U.S. newspaper coverage of food nanotechnology. Figure 3 shows that while 97 separate journalists penned food nanotechnology coverage, most of these journalists (77, 79%) wrote only one story. A mere 16 journalists (17%) wrote 2–5 articles, while only 4 journalists (4%) wrote 6 or more articles about food nanotechnology. Table 2 includes details about the most productive group of food nanotechnology journalists, including their names, newspaper affiliations, and the number of articles they authored. Two of these 4 journalists––Barnaby J. Feder of *The New York Times* and Rick Weiss at *The Washington Post*––have recently left the newspaper industry.

3.3. Themes

RQ3 asked how often six content themes––that is, themes that broadly link food nanotechnology to various aspects of society––have appeared in U.S. newspaper articles about food nanotechnology. The content themes were separated into two dimensions: consumer themes and sector themes. Figure 4 shows the extent to which the consumer themes (quality/safety, packaging, and food consumption) have appeared in coverage over the last decade. Some clear patterns emerge. Overall, the quality/safety theme has appeared most often in newspaper coverage of food nanotechnology. The quality/safety theme has been mentioned more than 3 times per news article since 2004, and was mentioned most often––an average of 5 times per news article––in 2006. The packaging theme, a related component of the quality/safety theme, has appeared less often than the quality/safety theme, but has experience some spikes in coverage, most notably from 2006 to 2007 when it jumped from slightly less than one mention per news story to approximately 4.5 mentions. In 2009, the packaging theme appeared an average of 2 times per news story. Of the three consumer themes, the food consumption theme has appeared the least. Its zenith was in 2000 (mentioned approximately twice per news story), but has, overall, been mentioned approximately once per news story over the last decade. Since 2007, however, the presence of the consumption theme has been slightly increasing.

Figure 5 shows that some clear patterns also emerge for the second dimension of the content themes: the sector themes. Overall, the business theme has been most predominant in U.S. newspaper coverage of food nanotechnology since 1999. At minimum, it has been mentioned approximately 4 times per news article, and has been mentioned more than 6 times per article in 7 of the last 10 years, most recently in the 2009 coverage. The business theme experienced its coverage zenith in 2004 when it appeared an average of approximately 10 times per story. Compared to the business theme, the other two sector themes––agriculture and regulations––have appeared far less often, overall appearing approximately twice per story throughout the last decade. Both themes experienced recent spikes in coverage (e.g., regulations were mentioned more than 4 times per story in 2006, and agriculture was mentioned approximately 4 times per story in 2007), but, on average, appeared less than twice per story in 2009.

In addition to the six content themes, we also examined how often our sample of food nanotechnology stories contained three specific conceptual themes, that is, themes that represent conceptually important dimensions of reporting about science and technology. Figure 6 illustrates the average number of mentions per story during the last decade for the conceptual themes: risks, benefits, and uncertainty. Most notably, the overall appearance of risks and benefits throughout the last decade is

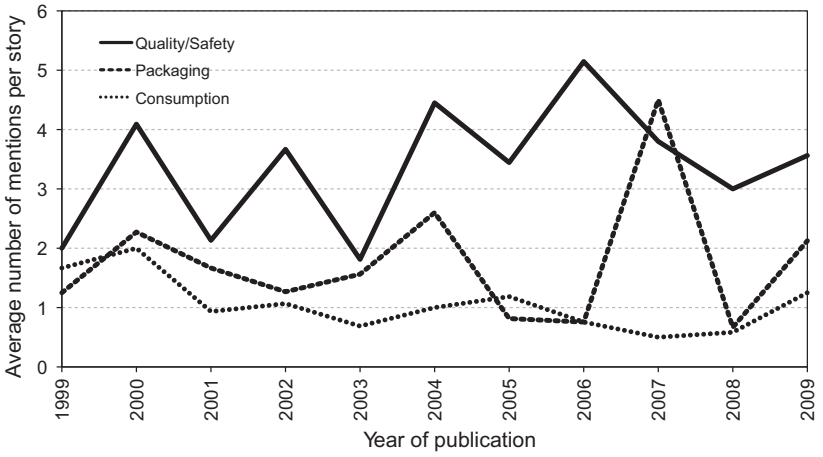

Fig. 4. Presence of consumer themes in newspaper stories about food nanotechnology.

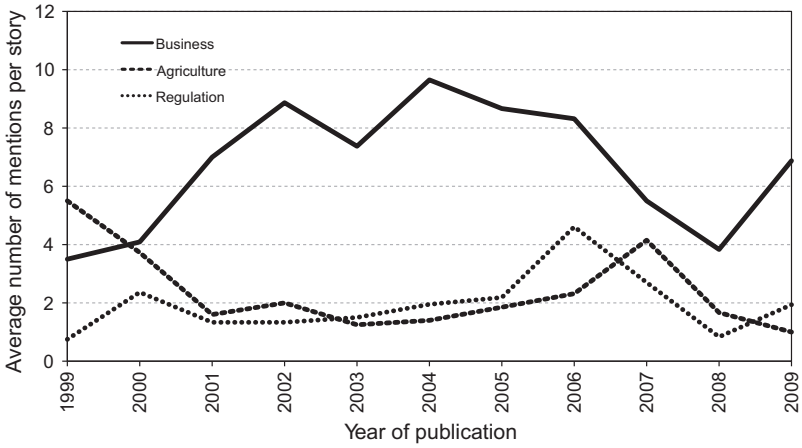

Fig. 5. Presence of sector themes in newspaper stories about food nanotechnology.

similar despite the many yearly fluctuations in the average number of times these two themes appeared. In other words, the average presence and absence of the risks and benefits themes in food nanotechnology coverage is characterized by covariance––both themes are mentioned, roughly, the same amount in each year's coverage over the last decade. The most obvious difference occurs between 2005 and 2007, the only time period during which risks, on average, are mentioned more often than benefits. Additionally, the presence of both risks and benefits has been steadily diminishing since 2007. The uncertainty theme has been essentially absent from coverage; it has been mentioned an average of less than once per news story in every year since 1999.

4. Discussion

The level of public acceptance, confidence, and trust will largely determine the success or failure of innovations made possible by food nanotechnology (Buzby, 2010; Chaudhry et al., 2008). For novel issues like food nanotechnology, media can play an important role in shaping the awareness and mental associations that underlie public opinion. Seeking to complement recent research exploring public opinion formation about food nanotechnology (e.g., Siegrist et al., 2007, 2008, 2009), this study tracked the evolution of U.S. newspaper coverage of food nanotechnology, identifying the descriptive and thematic traits that have characterized this coverage over time. We used a rigorous methodology to examine the levels of coverage, authorship patterns, and thematic emphases exhibited in the American journalistic narrative about this burgeoning application of nanoscience. Our findings indicate that U.S. newspaper coverage of food nanotechnology is relatively modest in terms of how often it has been covered, its thematic diversity, and the level of journalistic expertise from which it was produced. To our knowledge, this is the first study to empirically assess journalistic coverage of food nanotechnology.

Before discussing the implications of our findings, we should clarify some limitations. First, although our sampling technique (specifically our complex Boolean search term) returned an extensive number of stories, our sample might have been even larger by using a hybrid of LexisNexis and other online sampling techniques (for a discussion, see, Weaver & Bimber, 2009). Second, as content analysts are well aware, using computer-aided coding techniques have benefits and detriments. While our methodology allowed us to maximize reliability, it can come at the expense of validity, specifically in terms of examining latent meaning in coverage (Nacos et al., 2009; Riffe, Lacy, & Fico, 2005). We were cognizant of this trade-off, however, and as detailed earlier in our methods took numerous steps to maximize the validity of our

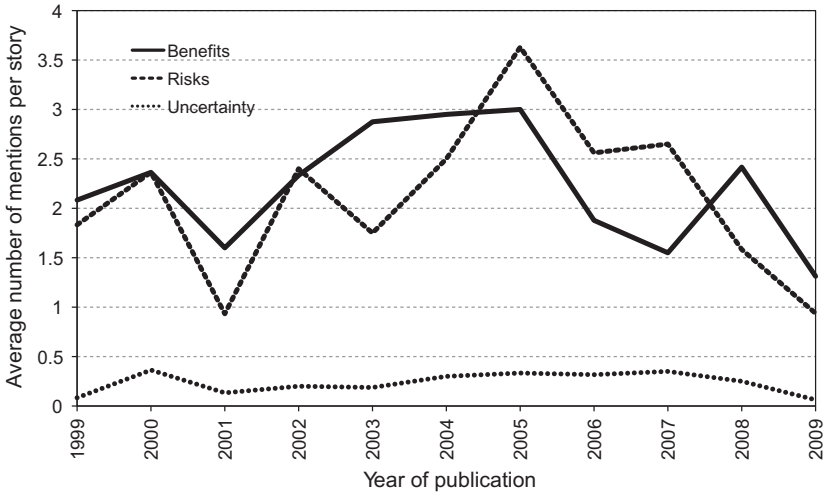

Fig. 6. Presence of conceptual themes in newspaper stories about food nanotechnology.

analysis as well.[4] We encourage researchers who build on our levels of analysis to help reveal an even richer picture of media treatment of food nanotechnology via human coding methods. One final limitation of our study is evident in its focus on newspapers. Although our goal was to parse U.S. journalistic treatment of food nanotechnology, it is important to understand that substantial shifts are occurring in audiences of science news. Recent surveys show that the Internet is fast becoming an outlet of choice for acquiring news about science and technology (National Science Board, 2010; The Pew Research Center, 2008a). With this in mind, additional research examining news coverage of food nanotechnology should include Internet and television coverage.

Not surprisingly, the emergence of food nanotechnology coverage coincides with the onset of food nanotechnology research in 1999 (House of Lords, 2010). Since 1999 the coverage trend has echoed that of general nanotechnology coverage, but on a smaller scale: the amount of stories increased steadily until 2006, then began diminishing. At first glance this flatlining of media attention might seem counterintuitive given the continued growth of food nanotechnology research and development, but there are at least two likely explanations for the recent stagnation. First, it is possible that the kind of news events that would attract journalists' attention to this topic have been rare in recent years. For example, food nanotechnology events were rather scant in the last three years, compared to 2006 when at least three noteworthy events occurred that undoubtedly helped create the coverage spike that happened in that year.[5] The recent decline in food nanotechnology coverage is also a likely result of the radical, ongoing changes within U.S. science journalism. The current downsizing trend in American newspapers has been particularly visible among science writers and reporters (Mooney, 2008; Mooney & Kirshenbaum, 2009a, 2009b; Nature, 2009) and mass media outlets, including newspapers, are devoting only a small percentage of their news hole to science and technology compared to other issues (The Pew Research Center, 2008b). These changes to the media landscape make sustained (let alone, increased) journalistic coverage of food nanotechnology even less likely going forward, although we would be remiss not to point out that major developments in this area––particularly developments that introduce controversy––are likely to spark ample journalistic attention.

Our authorship analysis finds that a small handful of journalists have penned a large proportion of articles about food nanotechnology. Just over 80 percent of the journalists in our sample have authored only one story, while only 4 individual journalists wrote 6 or more articles yet accounted for more than 20% of total reporting on food nanotechnology. This result has potentially serious implications. While it is common for a group of specialist reporters to dominate coverage of scientific issues (Dunwoody, 1980), in the case of food nanotechnology, it appears this group is especially small. What is more, two of these four journalists––Barnaby Feder of *The New York Times* and Rick Weiss of *The Washington Post*––are no longer working as journalists. In other words, a vast majority of food nanotechnology stories are written by journalists whose major area of expertise is not nanotechnology, or even science journalism. And the small cadre of science journalists who could provide insight and continuity in this specific area of coverage is shrinking.

These changes will have dramatic effects on the coverage of food nanotechnology, not only in terms of how frequently it is addressed, but it terms of how it is covered. Dwindling resources and fewer feet on the ground will obviously translate to less coverage of food nanotechnology. And of those reporters who remain, our analysis suggests the fewer of them have extended experience covering this issue. Together, these shifts suggest that future coverage of food nanotechnology is likely to become more event-driven and devoid of the more thoughtful treatments that specialist reporters are able to provide.

We found minimal diversity in the thematic associations present in news coverage. Business has far and away been the most common theme. It has been mentioned an average of more than 6 times per article in 7 of the last 10 years, most recently in 2009. The prevalence of the business theme is not surprising given the rapid pace of investment and scientific innovation in food nanotechnology (Brody, 2010; Kuzma & VerHage, 2006) and its dominance in general nanotechnology news coverage (Dudo et al., in press). By comparison, mentions of regulations and agriculture have appeared far less often. How the press cover regulations related to food nanotechnology in ensuing years could have considerable implications. It is widely known that the level of trust people have for industry and regulators influence risk perceptions (Priest, 2008). Recent research shows us that individuals are more likely to accept food nanotechnology when they have higher levels of trust in the food industry (Siegrist et al., 2007, 2008; Siegrist, 2008) and perceive higher levels of control regarding food nanotechnologies (Siegrist et al., 2008). In light of these findings, news about regulatory deficits or industrial reticence about food nanotechnology innovations could be especially problematic. Indeed, these regulatory deficits already exist (Buzby, 2010; Chaudhry et al., 2008) and the recent U.K. House of Lords report, Nanotechnologies and Food (2010), specifically laments the existence of these deficits and secretiveness. And despite the duress of U.S. journalism, newspapers will be quick to cover regulatory gaps and subterfuge, coverage that can only attenuate the level of trust and efficacy individuals' feel toward food nanotechnology.

Of the consumer-oriented themes we examined, mentions of quality/safety have appeared most often, and mentions of packaging have spiked recently in 2007 and 2009. The food consumption theme has appeared the least, but has been increasing slightly since 2007. Overall, it seems consumer-oriented themes are being mentioned more often in recent years. This upward trend, if it continues, has the potential to make individuals more aware of how they are most likely to come into personal contact with food nanotechnologies and their associated benefits and risks. Of central importance, therefore, will be examining the tone of these themes. Our analysis examined only the relative presence of these themes, but future research parsing the tone of these associations (e.g., whether food nanotechnology is written about as a boon or detriment to quality/safety, whether the consumption of nano-derived foods will promote or erode health, etc.) would represent a logical and important next step to our research. Moreover, this type of analysis would help contextualize recent work suggesting that individuals perceive nano-derived food packaging as more beneficial than nano-derived foods (Siegrist et al., 2007, 2008) and are more likely to accept food nanotechnologies when they perceive higher levels of naturalness in the products (Siegrist, 2008; Siegrist et al., 2008, 2009).

[4] It is reasonable to wonder about the efficacy of computer-assisted content analysis. Software can be used improperly and can yield inaccurate data. The likelihood of these negative outcomes increases when computer analysis relies on unproven software or is used to examine subjective concepts (e.g., latent content, associations among textual elements, etc.). Numerous content analysts, however, agree that computer analysis can be especially suitable for analyzing simple, manifest aspects of text, like the presence of words (Althaus, Edy, & Phalen, 2001; Conway, 2006; Evans, 1996; Hertog, 1990; Hocking, Stacks, & McDermott, 2003; Linderman, 2001; Riffe et al., 2005). With these considerations in mind, we used a reputable software program (Filemaker Pro) to examine straightforward, manifest content: keywords. In sum, we used the computer-driven approach conservatively and are confident that it yielded accurate results.

[5] (1) The U.S. Environmental Protection Agency declared on November 22, 2006 its intention to regulate a large class of consumer items made with silver nanoparticles (Garber, 2006), (2) The Sharper Image announced the launch of its exclusive FresherLonger ™ Miracle Food Storage Containers (Business Wire, 2006) and (3) the U.S. Food and Drug Administration formed the Internal Nanotechnology Task Force (Hampton, 2006).

We also found that mentions of risks and benefits related to food nanotechnology have been relatively equitable in any given year of coverage, and have been lessening in recent years. These findings are inconsistent with analyses of nanotechnology media coverage that found an overall emphasis on benefits rather than risks (Gorss & Lewenstein, 2005; Gaskell et al., 2005; Wilkinson et al., 2007) and increasing risk mentions in recent coverage (Dudo et al., in press; Weaver et al., 2009). These findings are also inconsistent with U.S. media coverage of agricultural biotechnology, which initially emphasized its benefits over its risks (Brossard & Nisbet, 2006; Nisbet & Lewenstein, 2002) and began giving increased play to more negative and ethical aspects of the technology in the late 1990s (Nisbet & Lewenstein, 2002). Individuals' perceived benefits and risks may influence their level of acceptance for new food technologies (for a discussion, see, Siegrist, 2008), but our results suggest U.S. newspaper accounts of this issue are not privileging either in any general sense. One explanation for this pattern might be that food nanotechnology is still a relatively new issue in the public domain. Once this novelty wears off, however, we might expect more divergence in the mentions of risk and benefit, namely that risk mentions will increase. Such a shift would be consistent with Downs (1972) issue attention cycle, which demonstrates how over time initial positive media coverage of an issue is replaced by emphases on the risks the issue poses for society. Increased media focus on the risks and uncertainties associated with food nanotechnology will only undermine individuals' sense of control, making public acceptance of food nanotechnology less likely (Siegrist et al., 2008).

4.1. Conclusion

Nanotechnology is dramatically transforming the food sector, spurring applications that have the potential to enhance the storage, texture, flavor, nutrition, quality, and freshness of food products (Chaudhry et al., 2008). This transformation, however, poses controversial implications for consumers, industry, and policy makers. Food nanotechnology is shrouded in uncertainty. In what ways might it endanger public health? How will it impact the environment? What modes of legal and regulatory oversight are needed to minimize its risks? Reflecting these questions and a need to understand the nascent social climate of food nanotechnology, we explore the demographic and thematic contours that have characterized U.S. journalistic accounts of this emerging issue thus far.Although journalistic coverage of other controversial technologies has increased and become more thematically complex over time (e.g., Nisbet, Brossard, & Kroepsch, 2003), it is difficult to predict how food nanotechnology coverage will evolve given the radical changes underway in the press and among news audiences. It may be tempting for individuals vested in food nanotechnology to gain comfort from the relatively benign coverage trends we have found. This interpretation, however, is a mistake for at least three reasons. First, although media can be an important factor in how the public regards nanotechnology (e.g., Scheufele & Lewenstein, 2005), it is crucial to remember that public opinion does not directly mirror media opinion (Priest, 2008). Second, media opinion is fickle. As we have noted earlier, it is likely that the amount and characteristics of food nanotechnology coverage could change quickly if a catalytic event occurs. The short burst of coverage following the *Magic Nano* health scare in Germany, Switzerland, and Austria (Weiss, 2006) is a good example.[6] This coverage, of course, ended quickly after it was discovered that the product in question did not in fact contain manufactured nanoparticles. Such shifts could undermine the levels of trust and efficacy and the types of risks and benefits individuals associate with food nanotechnologies––all of which are factors that public opinion research shows significantly influence individuals' degree of acceptance. And last, there are growing information gaps about nanotechnology. As previously mentioned, individuals with more education are learning more about nanotechnology, while their less educated counterparts' knowledge of nanotechnology is decreasing (Corley & Scheufele, 2010). The more stagnant food nanotechnology coverage is––both in terms of amount and quality––the more likely that these information gaps will persist or worsen. Although being more knowledgeable about scientific issues does not also mean being more supportive, the less quality information citizens have about food nanotechnology, the more volatile their opinions are likely to be.

[6] For another example of how a scientific message can ripple through media and have tangible effects on the marketplace success and policy-making related to new technologies—in this case, agricultural biotechnology—see Shelton and Roush (1999).

Appendix A. Newspaper sources with content about nanotechnology included in the sample

Medium	Large circulation[a]	Medium circulation	Small circulation
Newspaper[b]	The New York Times Washington Post Houston Chronicle The Boston Globe The Atlanta Journal-Constitution USA Today Star Tribune (Minneapolis)	The Plain Dealer (Cleveland) Milwaukee Journal Sentinel The Seattle Times St. Louis Post-Dispatch St. Petersburg Times The Sacramento Bee Pittsburgh Post-Gazette	The Augusta Chronicle Santa Fe New Mexican Bangor Daily News Lewiston Morning Tribune The Herald (Rock Hill) Star-News Wyoming Tribune-Eagle

[a] Large circulation was defined as >500,000. Medium circulation was defined as 100,000–499,999. Small circulation was defined as <99,999.

[b] In 2009, we were not longer able to access The Boston Globe, The Sacramento Bee, and the Seattle Times via LexisNexis. We replaced them with The Philadephia Inquirer, The Oregonian, and The Baltimore Sun.

Appendix B. Boolean term used to search the LexisNexis Academic database for news coverage of nanotechnology

atleast3(nanotech!) OR nanosci! OR nanoscal! OR nanocrystal* OR nanotube*OR nanomat! OR (nanometer* NOT W/15 light or laser or wavelength or UV) OR nanodot* OR nanomed! OR nanopart! OR nanowir! OR nanoeng! OR nanocomp! OR nanoelectric! OR nanoelectronic! OR nanobot* OR nanomachine* OR fullerene* OR buckminsterfullerene* OR fullerite* OR buckyball* OR buckypaper* OR buckytube* OR molecular assembl! OR molecular manufactur! OR micromachine* OR quantum dot* OR quantum wire* OR quantum well* OR sub micron OR (individual atom* w/5 manipulate or move or build) OR (scanning w/3 microscope*) OR (tunneling w/3 microscope*) AND NOT nanosecond* AND NOT apple AND NOT ipod AND NOT mp3 AND NOT digest AND NOT news w/2 brief* AND NOT business w/2 brief* AND NOT news summary

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