Crowdsourcing: A new conceptual view for food safety and quality

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Abstract

Background: Crowdsourcing is a new tool offered mainly over the internet for obtaining ideas, content, funding by seeking contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers. Crowdsourcing is widespread in numerous food applications (e.g., technology, entrepreneurial projects, start-ups funding, innovative product developments).

Scope and approach:
Although the use of crowdsourcing has increased rapidly, there is still much untapped potential in harnessing its vast innovative potential in food quality and safety solutions. This paper aims to review recent utilization of crowdsourcing practices in the food domain. Additionally, to furnish a conceptual view on possible application where crowdsourcing can be harnessed in enhancing food quality, safety and reducing risks.

Key findings and conclusions: It argues that crowdsourcing initiative is potentially a very useful tool as a part of the big data by utilizing the crowd's data in shelf-life monitoring, inventory control, foodborne illness surveillance, identification of contaminated products and to improve food businesses' hygiene, enhance food safety, communication and allergen management and minimizing risk. The limitations include the number of reports and data generated may overwhelm the food industry or authority due to lack of internal resources i.e. time and technical expert to process the information. There is also risk of lack of crowd participation and loss of control. Hence, a mechanism to facilitate, evaluate and process the data should be in place.

Keywords: Crowdfunding; open innovation; shelf-life; time-temperature indicator

Introduction

Crowdsourcing is a term first populated by Howe (2006), defined as taking a job that is traditionally performed in an organization by its employees and outsourcing it to a crowd of undefined network of

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people (non-employees) in the form of an open call. The crowdsourcing participants can be from anywhere, with various backgrounds, as long as they have Internet connection. The use of crowdsourcing in food related topics have also increased rapidly. For instance, Danone utilised crowdvoting which encourage consumers to vote for flavours of cream desserts. This operation attracted an increasing number of consumers (from 400,000 votes in 2006 to about 900,000 in 2011; Djelassi and Decoopman 2013). Similarly, Procter & Gamble, Starbucks and Unilever used crowd co-creation to find better product designs (Lutz, 2011). Lay's executed the crowd wisdom efficiently where over 245,825 chip flavours were proposed. Once the 2-finalists were shortlisted, Lay's utilized crowdvoting to determine the ultimate winner (Djelassi and Decoopman 2013). More recent crowdsourcing initiatives were launched with the help of eYeka. Nescafe reignited consumers' interest in instant coffee via 138 ideas from more than 40 countries. Winning ideas include coffee sticks and Soundcups where a Bistro-like experience is created via movement activated cups (Dinkovski, 2016). There is a trend for sourcing creative ideas from users particularly in designs, creative writing, illustrations and videos. For example, Coca Cola recently launches 'A Drink with Every Food Order' to crowdsource for ideas and graphic designs to convince consumers to choose drinks with their food (eYeka, n.d.a, b) while ZoOSh is sourcing for innovative videos to liven up food with ZoOSh flavours (eYeka, n.d.c).

Although crowdsourcing taxonomy suggests that it is open to anyone with access to Internet, there can be specific requirements for expertise, technical know-how and knowledge that may limit the participation. In addition to general crowd and experts, crowdsourcing taxonomy can be further divided into internal crowd (i.e. within the same organisation), crowd from research institutions and academia, external crowd such as specific online communities or public or via an intermediary facilitator (Simula and Ahola, 2014). It is worth noting that for large companies a crowd may also constitute by the firm's own employees could reach several hundred thousand people (e.g., Nestlé).

Essentially, crowdsourcing aims to harness ideas, feedback and solutions. Within an organisation, employers can source for fresh ideas by tapping into existing wisdom of their employees. Similarly, an open call for ideas such as new formulation, flavour, colour or packaging will be posted online to consumers. This expands their pool of collective ideas, hence reducing their reliance on specified experts or consultants (Simula and Ahola, 2014).

Crowdfunding

Crowdfunding is rooted in the broader concept of crowdsourcing where instead of using the crowd to obtain ideas and feedback, crowdfunding is used to raise capital for investment (Belleflamme et al., 2014). This alternative financial model was reported funding 27,500 ventures from 2012-2014 with UK leading the market segment ($2.4 billion), followed by France ($163 million) and Germany ($148 million) in 2014 (Wardrop et al., 2015). In 2012, the Jumpstart Our Business Startups (JOBS) Act came into fruition. Under the Act is the CROWDFUND Act which enables entrepreneurs to sell limited amounts of equity to investors via social networks and is exempted from expensive registration requirements (Stemler, 2013). Through these sites, entrepreneurs or small business owners who need financing for a new product or venture publish an appeal for funds and typically offer an incentive. Two popular crowdfunding websites such as Kickstarter and Indiegogo revealed in a recent search 279 and more than 500 food projects each seeking for financial resources from the crowd, respectively (Indiegogo, 2016; Kickstarter, 2016a).

Crowdfunding is an opportunity for food businesses and especially for small start-ups to generate funds or to raise its initial seed money. Through these sites, entrepreneurs and/or small business owners who need financing for a new product or venture publish an appeal for funds and typically offer an incentive. For instance, Anova precision cooker was the most funded project raising $1,811,321 in Kickstarter and had successfully launched its product for *sous vide* cooking by using a smartphone (Anova, 2015; Kickstarter, 2016b). Meanwhile small and portable sensors providing real-time results were designed and developed with the help of crowdfunding. One such product is Nima a pocket-size gluten tester by 6Sensorlabs (Crowdfund Insider, 2017). Nima is a sophisticated product that is able to detect up to 20ppm gluten in solids or liquid products. Similarly, other real-time portable devices such as the SCiO molecular sensing smartphone technology by Consumer Physics and Changhong H2 can help consumers to select fruits and vegetables, verify product authenticity and nutritional needs (Globes, 2017). SCiO is a spectroscope utilising near-infrared light to excite molecules to determine macronutrient values and food product quality. The readings obtained are analysed immediately and results will appear via the accompanying app (Coxworth, 2014). Although there are limited reports on crowdfunding in food safety projects, there are emerging sites for scientific projects in platforms such as Experiment.com, Medstart.com, Petridish.org and SciFund Challenge Network (Kuo, 2016). These initiatives can link donors i.e. public to visit scientific crowdfunding platforms and be reconnected to science (Schafer et al., 2016). In other words, crowdfunded projects can be part of researchers' public engagement and outreach efforts.

Crowdsourcing and new product development (NPD)

Food and drink start-ups are increasingly using the crowd and crowd-based platforms to leverage on the crowd to decide, innovate and create new products (Palacios et al., 2016). One major problem with newly introduced products is to anticipate what potential consumers actually need, i.e. which products they are willing or likely to buy. The failure rate of newly introduced products is still as high as about 40% (Castellion and Markham 2013) and could in many cases also reach 70 to 80%. Food and beverage firms that utilised crowd innovation to introduce new food products or beverages understood that consumers' preferences (and their ideas) can distinguish between product success or failure. In addition to developing new product ideas, crowd wisdom provides novel solutions, co-creation helps to develop outcome-based services and to pursue collaborative ventures while crowdfunding helps to raise capital (Palacios et al., 2016).

Typical examples of the aforementioned crowdsourcing practices are listed in Table 1. They include food and farming industries (e.g., Danone, General Mills, Unilever) that have utilized crowdsource for a plethora of food technology solutions. The examples listed project that the entire food supply chain is proactively involved in driving innovations using crowdsourcing. For example, My Farm and Bioversity International enables consumers to run a farm or to provide technical information of the best plant variety. However, most food processing companies harness crowdsourcing for creativity to develop new food and beverage flavours while retailers and catering services utilise its facilities such as Massive health eatery app (Gould, 2012) and Sourcemap.com (Hoffman, 2012) to provide food guides, traceability and carbon footprints of products.

Insert Table 1 about here

A recent literature search of the papers published during the last 3 years (2014 - October, 2016), included these keywords: "crowdsourcing" and "open innovation" was conducted. Some most current papers (Brown et al., 2016; Gustetic et al., 2015; Kavaliova et al., 2016; Mergel, 2015; Saez-Rodriguez et al., 2016; Schuhmacher et al., 2016; Wu et al., 2015; Zhuravlev and Nestik, 2016) highlighted these major points:

1. Food or the food industry were not mentioned.
2. Only one study focused on the collaboration between academia and food industry utilizing crowdsourcing but mainly focused on increased interactions with academia via academic excellence/innovation centers. No specifics was furnished if crowdsourcing was implemented (Tuffery, 2015).
3. The different roles of users in new product development (NPD) have been extensively described. Currently, online crowdsourcing for ideas are increasingly being used by companies to generate new product ideas from every day users (Schemmann et al., 2016).
4. Experts or research scientists had always been brought together (either face to face or via an online platform) to address a complex issue. This forms the initial concept of crowdsourcing – albeit sourcing ideas from a specified group of experts (Saez-Rodriguez et al., 2016).
5. The frequently referred to as a "crowd," was renamed as "complementors" and characterized as often unpaid, working outside of a price system and driven by heterogeneous sources of motivation. The study found that complementor development responds to platform growth even though they receive no payment. Instead of monetary incentives, complementors are motivated inherently by reputation, the need for learning, creating solutions and fun. Hence, it is important to understand

the underlying behavioural motives of complementors and the associated factors for contributing in an open, innovative platform (Boudreau and Jeppesen, 2015).

Crowdsourcing and open innovations (OI)

Crowdsourcing also falls within the remit of Open Innovation (OI). OI practices originated from software (e.g. open source software such as OpenOffice, Mozilla Firefox), wikies and telecommunication before spreading to pharmaceutical and the food industry (Gassmann et al., 2010). True to its name, OI has continuously evolved and today incorporates innovations in open business model, intellectual property (IP), strategy, collaboration, crowdsourcing, co-creation (Sloane, 2011), and social responsibility (Saguy, 2011, 2016; Saguy et al., 2013; Saguy and Sirotinskaya, 2014; Saguy and Sirotinskaya, 2016).

Value co-creation by crowdsourcing is a very powerful and efficient way of collaborating with customers/consumers and experts. More importantly, however, is recognizing its full potential by becoming an outstanding constellation of knowledge aggregation and product insights making it a very powerful OI tool. The question however still to be addressed is whether crowdsourcing is an efficient approach and match for OI, or its applicability should be limited due to its several inherent limitations. Obviously, benefits/risks involved, and consequently best practices should be considered and an in depth assessment is recommended before 'jumping' into this multidimensional and complex field. First, one should reiterate a well-known but sometimes ignored fact about the relationships between OI and IP. Although OI is founded on sharing and in most cases include IP, yet it is mainly created on profiting from licensing or any other arrangements allowing the use of one's IP, ideas or technology. Obviously, if crowdsourcing is carried out internally, this issue is not relevant.

The fundamental idea of internal crowdsourcing is to leverage the expertise and heterogeneous rich knowledge of a large industrial firm's employees' base. Employees may have better knowledge of the products, processes, operational parameters and services involved (Simula and Ahola, 2014). Multinational companies can also tap into their diverse and heterogeneous group of employees for collective wisdom. Alternatively, some companies can draw on their own internal (or external) networks and contacts that include experts in various fields. Combining experts (e.g., R&D, marketing, sales, process engineers), is therefore straightforward. As much as this process could be most effective and straightforward to be applied, its maintenance for a long period of time, it always faces problems and unless there is a constant mechanism for compensation, recognition and acknowledgment people tend to lose their interest and the tool becomes obsolete.

The other alternative is to use external crowdsourcing. In this case, addressing all the issues and setting the IPs where appropriate is probably the most difficult barrier in OI implementation and calls for thinking 'outside the box' so that the collaboration can be initiated and the outcome benefits can be shared. Although the '*Sharing Is Winning*' concept (Traitler and Saguy, 2009) was coined as an imperative part of OI, it does not mean that innovation is free or that IPs are compromised. Despite the general agreement that there is no innovation without IP, this topic is of crucial importance and needs careful consideration to avoid future possible issues. IP not only guarantee the rights of the inventors, it also protects the user companies from future allegations, possible dragging litigations and alleged negative publicity. This explains why most companies are dealing with OI of technology, scientific projects, development of equipment, and other ideas upfront. The actual collaboration in some cases starts only after all the IPs issues have been resolved and a clear agreement has been signed. This implies that the initial OI crowdsourcing first step of identifying the possible solution providers and/or partners are identified is open, while the next step typically follows a 'close system' paradigm. Hence, although crowdsourcing may be the first stage where the experts, technology or ingredients suppliers with unique know-how reply to a 'request for innovation' (RFI), and the proper candidates are identified and selected, the next step typically involves resolving the IPs issues before the actual work or real knowledge/technology exchange is initiated. It also means that either the originator company and/or the appropriate brokerage house (e.g. Ninesigma) is hired for this purpose. (It should be noted that in some models [e.g. Innocentive and many open innovation projects] the IP is addressed at the beginning of the process where companies can license or own the IP after reviewing the proposed work). The selected company should have the capability of collecting the applicants' information and suggestions, selecting those that fit the RFI, carrying out an assessment, negotiating the IPs and the reward mechanism, to mention only a few steps typically applied. These tasks are quite complicated and require often significant investment both in people time, expertise and resources, and could be time consuming and quite costly. Hence, it offers an explanation why some companies are reluctant to choose this avenue and prefer to utilize some other approaches such as scouting (e.g., internal employees, consultants, academia) to identify the possible external resource(s) and to alleviate the need for an open RFI call and crowdsourcing.

Firms (also known as seekers or initiators) that are seeking specific solutions commonly utilise an intermediary player (facilitator) to engage the crowd (solvers). Online intermediary platforms and social networks facilitate the call for solutions. For example, Facebook coupled with monitoring and engagement system such as Radian6, taps into social media users (with public settings) data and identifies consumers' preferences leading. The formulation of Gatorade (Constine 2011) is a typical example.

Intermediary facilitators are service providers such as InnoCentive, Kickstarter, Seedr (funding platform for entrepreneurs and investors) to connect the initiators or seekers with solvers. InnoCentive is an example of a successful facilitating platform by utilizing crowdsourcing to develop solutions to scientific problems. For instance, they launched a system linking outside experts to solve a pharmaceutical problem and also offered a monetary reward to the solver (Allio, 2004). Typically, clients or firms will seek out InnoCentive to post their projects on InnoCentive's platform, and a call for proposals/solutions will be initiated to registered members (solvers) of InnoCentive. Winning solutions receive cash prizes from the company seeking for solutions (InnoCentive 2016). It is obvious that crowdsourcing will be useless without participation from the various experts.

Other intermediary platform includes Amazon Mechanical Turk (AMT) which provides crowdsourcing service and permits researchers to pose tasks or questions which are then answered by a potential pool of 500,000 participants (known as MTurk or Turkers). AMT is an example of a novel data collecting platform and the Turkers complete short, "one-off" tasks for pay (Chandler and Kapelner, 2013). The participants sourced via AMT are demographically diverse (e.g. 40% participants were from America, 33% from India and the rest from about 100 other countries; The Economist, 2012), age range of 20 – 40 years and the majority is females (Mason and Suri, 2012) when compared to 'standard' Internet samples (Buhrmester et al., 2011). Other crowdsourcing service facilitators include oDesk, CrowdFlower and Elance (The Economist, 2012).

Crowdsourcing conceptualization on utilization for future food quality and safety

To date the utilization of crowdsourcing in food safety and quality is somewhat limited. One possible application is highlighted by the European Food Safety Authority that recognised the potential of using crowdsourcing for food and feed risk assessment, and issued a call for tender in late 2015 (EFSA, 2015). EFSA had initiated the discussion on crowdsourcing for food safety data by exploring the challenges and techniques on risk assessment initiation to risk communication and decision making. EFSA is notably one of the key EU agencies that had systematically utilised social media tools to interact with consumers (Spina, 2014). Indeed, the approach extends beyond the traditional risk assessment practices which rely on development and acquisition of data such as reviewing literature, performing measurements and expert elicitation. Moreover, only one hazard-food combination can be analysed at a specific time (Chardon and Evers, 2017; Nauta et al., 2007). An example of an exploratory crowdsourcing method would be to mine knowledge and expertise from online communities to conduct studies to feed into risk assessments, identify models that can be applied to safety assessments or to develop algorithms to improve data analysis (Drew, 2015; Verloo, 2016).

The authors suggest that this area is still in its infancy and its untapped vast potential was not fully utilized and/or implemented. Most probably the field will be developed in the near future and emerge as a very valuable tool. To highlight this avenue, the next part of this paper is devoted to the exploration on where and/or how to harness crowdsourcing in providing potential solutions in food quality and safety applications. Within this framework, we have identified some 'hotspots' topics or actors within the food supply chain and storage where crowdsourcing can be initiated.

Crowdsourcing for future data and food safety solutions

First and foremost, the crowd in food quality, safety and risk assessment should be defined. Food safety experts are individuals with the (scientific) knowledge to potentially make informed sound judgements. Food safety experts provide sound judgement about the likelihood that illness from a particular pathogen is attributable to particular foods (Hoffmann et al., 2007). Harnessing data from experts can be carried out via in-depth interviews, a formal written elicitation instrument (Hoffmann et al., 2007), or utilizing a Delphi process in which a consensus of opinion among experts is obtained (De Boer et al., 2005). Expert elicitation had been used as a method to crowdsource for possible solutions – albeit with a smaller number of respondents. Food safety experts' opinions are a valid approach especially when there is insufficient or realistic data are not available (Pujol et al., 2015). Experts can provide both short (i.e., food safety issues that require immediate action such as during microbiological outbreaks) and long term food safety solutions (e.g. identification and preventive or reduction of contaminants method). There is benefit in seeking experiential views on a topic or by soliciting for expert opinion. This itself represents a fundamental challenge to overcome. Some of the questions that might arise are, 'How do we legitimate experience and scientific judgement and separate this from personal opinion?' Or, 'how do we ensure experts only comment on the area they are experts in?'(Soon and Baines, 2013). This can be addressed by first setting the selection/inclusion criteria of the experts followed by the basis for the experts to make their judgements. Additionally, one can define the relevant experience and professional legitimacy of respondents, then crowdsourcing for ideas, concepts and solutions can be informative and creative. Via continuous research, development and sharing of outputs, the expert group can provide feedback and scientific support to food authorities and private food businesses. Meanwhile in the age of social media, the crowd representing the consumers can be anyone with a computer, smartphone and Internet access (Rousseau, 2016). Consumers can review restaurants, blog about their food experiences, publish recipes and photo sharing. Crowdsourcing initiatives among consumers had been applied in the area of food safety particularly in foodborne illness and outbreak surveillance (Hu et al., 2016; Kaufman et al., 2014; Nsoesie et al., 2015; Quade, 2016). Kaufman et al. (2014) and Kaufman (2016) also tapped on the potential of sales data in the food supply chain to identify contaminated food products. Prior to Kaufman's initiatives, public health officials had requested for permission and utilized customers' loyalty card and warehouse membership to analyse grocery purchases. The loyalty and membership cards provided valuable information whilst investigating outbreaks (Barret et al., 2013; Gieraltowski et al., 2013). Meanwhile Sadilek (2016) utilized Twitter's data to capture the potential number of patrons who fell ill after eating at certain venues. Quade (2016) and reports from Siegner (2015) demonstrated the effectiveness of the foodborne illness reporting via the 'Iwaspoisoned.com' website. Nsoesie (2016) also utilize social media and business review site such as Yelp.com to mine data on foodborne illness and outbreaks. The real time monitoring and processing of crowd data helps to aid traditional surveillance and restaurant inspection systems and the crowd are provided with an 'outlet' or platform to share their experiences of being sickened by restaurant food. There is still untapped potential that can be harnessed from the crowd using social media as the driving and reporting vehicle. Other potential areas that are worth investigating include crowdvoting of cleanliness and hygiene of restaurants and effectiveness of allergen management and communication provided by food services.

The consumers represent the bigger crowd in the food safety arena and their responses; such as positive and negative reviews of food products, restaurants, unhygienic food outlets and twittering about foodborne illness symptoms will help to connect the dots in big data analytics. For example, consumers' data, votes and ideas can be harnessed by including their responses in designated food safety / authority sites / mobile applications and monitoring via social media network. Examples include crowdvoting of cleanliness or hygiene of food businesses or crowdvoting of food businesses that manage and communicate allergen information effectively to consumers. However, there remains the challenge of determining the reliability of consumers' views. However, consumers' views, votes or scores can become meaningful when generated across large populations (Ginsberg *et al*., 2009; Soon *et al*., 2016). These data can be fed back to the industry or specific food businesses that utilise crowdsourcing practices. Food industry must be aware that the crowdsourcing initiatives in food safety is not a marketing or promotional tool, but involves a complex process and is driven by open innovations. At the same time, these data can be mined and monitored by the authority to take corrective or preventive actions if necessary. These represent simplified examples of crowdsourcing practice that can be easily implemented, represents real-time monitoring and has the ability to provide critical awareness of food safety issues to food businesses.

Experts and consumers (layperson) have different opinions about risks; for example, experts are driven by scientific objectivity, quantitative assessment of product properties like quality, microbial level and nutritional value and probability while consumers' perceptions relate to human subjectivity and pay more attention to consequences (Soon and Baines, 2013; Verbeke et al., 2007). Although both groups have differing perceptions, the motivation to provide possible solutions and to create awareness essentially drives the crowdsourcing initiatives in food safety and quality solutions. The driving force for these innovative crowdsourcing ideas is to provide safe food. This group can be defined as '*a motivated group of individuals who actively demand for safe food and strive to create awareness among themselves, the authority and media with the hope of developing a safer food supply chain'.*

Future crowdsourcing utilization: Shelf life and food inventory rotation

Food product rotation is utilized to ensure that older stock is sold first. This routine is applied for a large number of foods with shorter shelf life (e.g., frozen, refrigerated), but could be also implemented for those food products with much longer shelf life (e.g., canned). Open dating is a common practice and applies to all food products and drugs, and is an essential element achieving stock rotation at retail, and simultaneously provides valuable and essential information to consumers as also required by regulations. Open dating provides a simple communication tool, which may be based on product quality and/or food safety as determined by the manufacturer. The variation in date labelling terms and usages contributes to substantial misunderstanding by industry and consumers and leads to significant unnecessary confusion, misapplication of limited resources and food losses and waste. Food waste is estimated at 1/3 of the total global food production every year. The cost for food waste is estimated at US$ 680 billion in developed nations while developing countries were estimated at US$ 310 billion. Most of the losses in the developing countries occurred at the farm and during storage due to absence of storage technologies and infrastructure. If temperature control cannot be assured throughout the food supply chain, this defeats the reliance on open dating system such as "use by" or similar date labelling as an indicator or guarantee for food safety (Newsome et al., 2014). The following section focus on Time Temperature Indicators (TTI) and its potential usage in shelf life and food inventory rotation. Although TTI per se is not a crowdsourcing method, but the data generated will benefit the users or crowd throughout the food supply chain.

Time Temperature Indicators (TTI) are used to monitor the temperature conditions during distribution (Giannoglou et al., 2014). TTI usage and applications had been previously reported ((Fu et al., 1992; Giannakourou et al., 2001; Giannoglou et al., 2014; Taoukis et al., 1999; Taoukis et al., 1997; Tsironi et al., 2008). The authors had reviewed the potential of TTIs as food quality monitors during distribution and storage and recommended that an improved product quality monitoring and stock rotation system be implemented. This new approach could complement or even replace the First In, First Out (FIFO) system. The FIFO system had always been based on selling food products that arrived first (or closest to the expiry date on the label). Taoukis et al. (1998) proposed an alternative TTI system known as the Least Shelf Life First Out (LSFO) system for chilled products. The rotation and distribution of food products based on LSFO principles led to more consistent product quality at time of consumption. For example, Giannakourou and Taoukis (2003) revealed that 5.1% of FIFO products were beyond acceptable quality at time of consumption. In contrast, LSFO managed to eliminate products with unacceptable quality. However, the practicality of TTI quality monitoring is also dependent on the data collected. It may be challenging for a company with a large consumer base, spanning over a wide area and multiple distribution channels to collect the data. Hence, manufacturers may be restricted in monitoring their products and collection of data due to the high cost required for continuous monitoring of TTI through the supply chain.

However, the wide spread of smartphones equipped with improved camera high quality and via the utilization of crowdsourcing, big data and cloud computing open a completely new option that offers entirely new tools and opportunities for the food manufactures to reconsider and manage their food products rotation and shelf life consideration. The possibility for any consumer to scanned a simple TTI equipped with an extended and unique universal product code (UPC) allowing full identification of each and every package and monitoring the product quality by scanning the TTI and feeding the info into the manufacture or a public database. The apps can then project on the screen the prediction utilized by the manufacture shelf life model highlighting the product quality and other pertinent information.

Future utilization of crowdsourcing to monitor TTI offers these unique benefits:

- Communication with the manufacture or public database offer accurate knowledge of the various distribution chain conditions, calculating the quality lost/remained, and identifying possible abuse conditions.
- Dynamic shelf life assessment offering consumers a possibility to consume safe products and avoiding consuming low quality products.
- Reducing waste by changing the terminology of the term 'best by' to a different and more consumer friendly communication.
- Identifying and warning the final consumer not to use a low quality product that was abused throughout the distribution/retail chains including also home storage.
- An accurate method for defining food shelf life based on the various geographical regions and external weather conditions, and food practices.
- Identifying distribution lines and/or stores that handles products inappropriately and offering the possibility for better control and educate.
- Improves consumers' communication and enhancing their confidence in products quality, safety and wholesomeness.
- Offering consumers valuable information on the quality of their products before or close to the shelf life expiration date in order to reduce waste.
- The data collected can be also utilized to improve shelf life and quality prediction and development of new and improved mathematical models.
- Expanding the system and its utilization for other purposes such as recalls and/or continuous database information system that allows two-way quality communications with stores, retail chains and consumers.
- Stock rotation and distribution system management based on LSFO.

It is apparent that the above list is non-exhaustive and can potentially be expanded to other fields and applications, such as drug and science-data-rich kinetic models and a plethora of other utilizations to be made possible by cloud computing and big data technology. It is also clear that for the method to work effectively, the crowdsourcing should be made straightforward extending the users visible benefits to consumers, manufactures, and others. For instance, combining machine learning, crowdsourcing and experts knowledge to detect chemical-induced diseases in text mining and drug side effect was already described (Bravo et al., 2016).

TTI are essential and cardinal part of this future new application of combing crowdsourcing for monitoring real time temperature data. TTI cost has been reduced significantly since their inception, thus it is no longer a real unpassable barrier limiting their wide spread utilization. TTI ability to accurately correlate with some quality attributes has been demonstrated for various applications (Giannoglou et al., 2014). Yet, it is expected that the rich data provided through crowdsourcing will be combined with advanced and sophisticated new approaches in utilizing machine learning, artificial intelligence and other data mining techniques for the development of improved kinetic accurate models.

The new information collected could be also instrumental in the development of innovative new date-labeling practices offering regulatory and other food authorities in one or several countries, to address misconceptions about date labeling and the extent of adverse impacts of those misreading as was also suggested previously (Newsome et al., 2014). The data that will be collected is anticipated to open new data-rich information and detailed databases clarifying issues of food shelf life, date labeling of food products, improving consumers' confidence and utilization, and contributing to the overall battle to curtain food waste and losses.

TTI Indicators utilization is just one key example among a plethora of new other possibilities and vast potential offered by combining advanced sensing and smartphones. For instance, according to Consumer Physics Inc. (http://www.globes.co.il/en/article-consumer-physics-unveils-molecular-sensing-smartphone-1001170338; accessed Jan. 7, 2017) the SCiO sensor (a miniature spectroscope utilizing near-infrared light) was developed, and by teaming with China's Changhong Electric Co. and US chipmaker Analog Devices Inc. unveiled the world's first molecular sensing smartphone. This technology was reported to allow consumers for the first time to scan with their smartphones and immediately receive actionable insights based on its underlying chemical composition, and their molecular makeup. Hence, opening the possibility for consumers to analyse the properties of foods, liquids, medication, body metrics, and others and probably address general issues related also to food safety. The Changhong Company is also working to create a broad eco-system of mobile applications that utilize the Consumer Physics Inc.'s SCiO sensor for a wide range of other uses. It is interesting to note that the company is backed by Khosla Ventures and OurCrowd, among others. Also Consumer Physics also raised $3 million on Kickstarter – a crowdfund source. Consumer Physics Inc. believes that the Changhong H2 phone will unleash a tsunami of other applications. Another example is C_2Sense's sensor chip with 4 sensing elements on plastic, for detecting up to 4 compounds (e.g., ethylene for fruit freshness, biogenic amines for meat/fish/poultry freshness, humidity and carbon dioxide) simultaneously (https://www.wired.com/2015/11/c2sense/; accessed Jan. 7, 2017). C_2Sense's tiny chip gives computers a sense of smell and in the future it could probably incorporated in a smartphone application. The ability to sense ethylene at very low concentration by utilizing smartphones opens a new avenue to reduce postharvest produce losses by managing stocks based on quality characteristic parameters. Additional examples where Startups take bite out of food poisoning were described already few years ago (Mims, 2014).

It should be however emphasized that verification of the information and in depth assessment of its possible utilization, sensitivity, repeatability and accuracy should be tested and demonstrated under real field of distribution and storage conditions before this technology could be commercialized and fully utilized. Moreover, the utilization of social media carries also a heavy and increasing burden to ensure that the system is not abused. Individuals and organizations have found ways to exploit these platforms to spread misinformation, to attack and smear others, or to deceive and manipulate. The lack of effective content verification systems on many of these platforms call for significant precaution to ensure the accuracy and validity of the data collected. This issue needs to be fully considered and its negative potential impact taken into consideration to avoid the harmful and damaging exploitations.

Other possible benefits of crowdsourcing in food safety

Some of the immediate benefits of crowdsourcing practices in food safety are the potential to collate, compare or benchmark foodborne illnesses' reports. For example, iwaspoisoned.com played a crucial role in the outbreak linked to a Chitpotle restaurants (https://chipotle.com/), while mining the data from Yelp.com revealed a similar indication to the one reported by the US Centers for Disease Control and Prevention. This will largely assist the public health departments to further investigate and inspect restaurants. Similarly, processed data from Twitter and sales data can potentially prevent cases of foodborne illnesses and identify implicated food products that contain the real outbreak source (Kaufman, 2016; Nsoesie et al., 2015; Quade, 2016; Sadilek, 2016). Other possible benefits include identification of contaminated food products, outbreak surveillance, reports on hygiene and allergen management can provide substantial information for food authorities and public. Crowds can also be utilised in various food safety projects such as providing ideas and recommendations (e.g. restaurants with 5-star hygiene rating), contributes to product testing and improvement (e.g. invited to be beta-testers for Nima gluten tester) and participates in data analysis (e.g. development of algorithm for risk assessments or IT platforms).

Crowdsourcing for food safety solutions obviously benefit a number of stakeholders (consumer/customers, industry, state, authority). Based on the above scenario, the most obvious recipient is the crowd (or public). The increased and improved foodborne illness surveillance, monitoring of potential outbreaks, identification of contaminated foods and reports regarding cleanliness and cross contamination of food safety hazards and allergens can reduce number of foodborne illnesses. Food authorities can utilise the processed crowd information to adapt their inspections or surprised audits. Similarly, food businesses can utilize the information to improve their food safety management systems and preventive measures. Another possible benefits of crowdsourcing is the contribution it could offer to the Global Harmonization Initiative (GHI; http://www.globalharmonization.net/) – an international non-profit network of individual scientists and scientific organizations working together to promote harmonization of global food safety regulations and legislation. Crowdsourcing could provide the means an opportunity to engage and empower food scientists and experts in industry, government and academia to voice scientific consensus and make recommendations on food safety laws and regulations, globally. Thus meeting the GHI's aim is to provide objective and fact-based advice that will help harmonize conflicting regulations and legal policies. Crowdsourcing in this case could help GHI's achieve some of their aims such as promoting the use of innovative food safety technologies around the globe, reduce foodborne diseases and outbreaks.

Incentive or Reward Mechanism

Archak (2010) reported that monetary incentive played a crucial role in encouraging the crowd to contribute their ideas. For example, InnoCentive provide monetary awards in exchange for the best solutions or ideas. Similarly, Lay's Create your Potato Flavour' winner was rewarded with cash incentive as well as 1% of the product's sales for a year (Dejelassi and Decoopman 2013). Although the number of applications of crowdsourcing in food safety and quality solutions are somewhat limited, the existing contributors or crowd were not motivated by monetary incentives. In fact, most were driven by the need to create the awareness about foodborne illnesses (e.g. iwaspoisoned.com) and to identify contaminated food (Hu et al., 2016; Kaufman, 2016; Nsoesie, 2016). This is akin to a form of altruism or unselfishness among the crowd (First Monday, 1998) or the crowd is passionate about the activity or participation (Franke and Shah 2003). Similarly, Lakhani et al. (2007) reported that the main motivational drive for experts or specialists were the enjoyment in solving scientific problems and cracking the challenge. When a task is complex, extrinsic motivations are more prevalent than intrinsic motivation (Hossain and Kauranen 2015). Having the free time or capacity to work on the problems is also a strong motivational driver. Social and work-related motivations such as career aspirations, professional reputation and being the first to solve a scientific challenge and beat others to it is a strong motivation for scientists (Lakhani et al., 2007). It is also used as a way to signal talent to peers and prospective employers (Lerner and Tirole, 2000). These are characterised as hedonic, experiential and symbolic (self-fulfilling) motivations (Djelassi and Decoopman 2013). It should be noted however that maintaining the crown engaged for a long period of time, is a major concern and this issue needs to be addressed.

Limitations of crowdsourcing in food safety

There are of course a number of limitations that should be considered prior to initiating the crowdsourcing practices. During crowdsourcing, the number of reports and data generated may overwhelm the food industry or authority due to lack of internal resources i.e. time and technical expert to process the information (Blohm et al. 2011). The IT platform should be sufficient to handle crowd traffic and facilitate active participation (Leimeister et al. 2009). There is also risk of lack of crowd participation and loss of control. Although crowdsourcing may have access to a large and diverse crowd, there may be food safety projects or tasks that fail to attract sufficient number or even result in a disproportionate influence of limited number of individuals (EFSA, 2015). Loss of control occurs when allowing outsiders to participate, an organization may lose control over the behaviour of the crowd and the outcome of the project as crowd may make unpredictable moves since they may not have the organisation's best interests at heart (Bonabeau, 2009). The aim or focus of the crowdsourcing should be clearly defined and a mechanism to facilitate, evaluate and process the data should be in place. The crowd data is only useful if the feedback are taken into consideration and food businesses (and authorities) took appropriate actions to improve their food safety problems.

A number of general risks are associated with crowdsourcing. For instance, lack of internal resources (Blohm et al., 2011), feeling of exploitation and being cheated (Djelassi and Decoopman, 2013), security and privacy risks (Gibbons, 2014) and unpredictable crowd moves (Bonabeau, 2009). Another main point is how does one guarantee that negative groups/people/interests are not blown out of proportion with far reaching ramifications? This issue requires very careful consideration due to the increasing negative incidents reported recently. There are however a number of options to control a negative crowd. For example, iwaspoisoned.com currently prevents visitors to the site from accessing the entire record of reported foodborne illnesses. This helps protecting previous food businesses that were reported on the site but had implemented corrective actions. Quade (2016) also cautions that one should interpret the reports with caution as there could be one geographic region with more smartphone users or motivated, tech-savvy individuals. Some of the reports may not be true foodborne illnesses i.e. it could be other reactions e.g. adverse reactions to allergens or intolerances. Hence a disclaimer to acknowledge the fact that not all foodborne illness information submitted to the site is accurate. There are also other related limitations such as 'How is crowdsourcing going to face the challenges in quality assurance of data?' This deals with finding sufficient and knowledgeable users as well as the ability to maintain a reasonable level of quality. Hence, attracting and picking the right crowd is important as the crowd will determine the average quality of ideas submitted which ultimately affects the average of quality of best ideas (Poetz and Schreier, 2012) and provides a more diverse set of solutions (Terwiesch and Xu, 2008).

Conclusion

There is potential for radical innovations and crowdsourcing in food safety and quality solutions. Crowdsourcing leverages on crowd's intelligence and is capable of aggregating talent while reducing time and costs. Crowdsourcing is only enabled through IT technology and requires continuous active participation, user interactivity and transparent feedback. Targeting and motivating the right crowd can assist food industry and authority in thinking in new trajectories. The above review clearly suggests that crowdsourcing found a wide spectrum of applications in food innovations. It is however somewhat limited in the area of food safety and quality. Crowdsourcing initiatives may be the means to harness food safety solutions, predict foodborne disease outbreaks, identify contaminated food products and improve hygiene, food safety and allergen management of food businesses. These data can be mined and monitored in real time to take corrective or preventive actions if necessary. Similarly, there is potential for crowdsourcing to be applied to complex food safety projects by engaging the crowd to develop algorithms to improve big data analytics, identify models that can be applied to safety assessments or to feed in data into risk assessments. Crowdsourcing may also be harnessed to reshape inventory control by using advanced TTI and to reconnect public to science and to exhibit openness and trust. Additional research is needed to facilitate the process especially on the collaboration between industry and academia as well as other solution providers. It is also recommended that several studies to be conducted in large food companies to highlight the specific benefits and best practices to enhance the applicability of crowdsourcing.

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Table 1 Typical crowdsourcing examples of various food and snack applications

Initiator or seeker	**Purpose**	**Crowd**	**Incentives for participants**	**References**
Anheuser-Busch (AB)	Developing new crowdsourced ideas for beer (Black Crown)	Brewmasters (12), consumer suggestions and tastings (estimated at 25,000 consumers)	Newly crafted beer; mixture of intrinsic and extrinsic motives – peer recognition by other brewmasters	Innocentive 2013; Martinez and Walton, 2013
Danone	Consumers to vote for flavours of cream desserts	Consumers (over 900,000 votes were received in 2011)	Intrinsic motives, fun, curiosity	Djelassi and Decoopman 2013
General Mills	Actively seeking OI partners to deliver	Hobbyists, engaged, loyal	Intrinsic motives, fun, curiosity	Innocentive 2013; General Mills

	innovations in ingredients, packaging, processing, products, technologies and sustainability	customers, experts? Suppliers? Others?		2015; Martinez and Walton, 2013
Kraft Food	To design a poster or print ad unique to mini-Oreo product	Crowdsourcing eYeka platform) of consumers from 42 countries (Hobbyists, engaged, loyal customers)	Inspired new brand positioning for mini-Oreo; Intrinsic motives, fun, curiosity	eYeka n.d.d; Martinez and Walton, 2013
Lay's	Creation of new potato chip flavours. Received 245,825 flavour proposals of which 108,729 were unique. Two winning flavours were selected and sold in stores in 2011	Consumers	Rewarded with Euro 25,000, 1% of the product's sales for a year and has his or her name on the product	Djelassi and Decoopman 2013
Unilever	To OI source for new technique, packaging, fresh design or formula (e.g. to find salt alternatives or technology to retain natural green colour of herbs and vegetables in long shelf life food products)	Hobbyists, engaged, loyal customers	Potential product supply, license, joint venture, technology acquisition or patent acquisition if submission if of interest; Intrinsic motives, fun, curiosity	Innocentive 2013; Martinez and Walton, 2013;Unilever 2015