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

55

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

63

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

69

70 **Crowdfunding**

71 Crowdfunding is rooted in the broader concept of crowdsourcing where instead of using the crowd to
72 obtain ideas and feedback, crowdfunding is used to raise capital for investment (Belleflamme et al.,
73 2014). This alternative financial model was reported funding 27,500 ventures from 2012-2014 with UK
74 leading the market segment (\$2.4 billion), followed by France (\$163 million) and Germany (\$148
75 million) in 2014 (Wardrop et al., 2015). In 2012, the Jumpstart Our Business Startups (JOBS) Act came

76 into fruition. Under the Act is the CROWDFUND Act which enables entrepreneurs to sell limited amounts
77 of equity to investors via social networks and is exempted from expensive registration requirements
78 (Stemler, 2013). Through these sites, entrepreneurs or small business owners who need financing for
79 a new product or venture publish an appeal for funds and typically offer an incentive. Two popular
80 crowdfunding websites such as Kickstarter and Indiegogo revealed in a recent search 279 and more
81 than 500 food projects each seeking for financial resources from the crowd, respectively (Indiegogo,
82 2016; Kickstarter, 2016a).

83
84 Crowdfunding is an opportunity for food businesses and especially for small start-ups to generate funds
85 or to raise its initial seed money. Through these sites, entrepreneurs and/or small business owners who
86 need financing for a new product or venture publish an appeal for funds and typically offer an incentive.
87 For instance, Anova precision cooker was the most funded project raising \$1,811,321 in Kickstarter and
88 had successfully launched its product for *sous vide* cooking by using a smartphone (Anova, 2015;
89 Kickstarter, 2016b). Meanwhile small and portable sensors providing real-time results were designed
90 and developed with the help of crowdfunding. One such product is Nima a pocket-size gluten tester by
91 6Sensorlabs (Crowdfund Insider, 2017). Nima is a sophisticated product that is able to detect up to
92 20ppm gluten in solids or liquid products. Similarly, other real-time portable devices such as the SCiO
93 molecular sensing smartphone technology by Consumer Physics and Changhong H2 can help consumers
94 to select fruits and vegetables, verify product authenticity and nutritional needs (Globes, 2017). SCiO
95 is a spectroscope utilising near-infrared light to excite molecules to determine macronutrient values and
96 food product quality. The readings obtained are analysed immediately and results will appear via the
97 accompanying app (Coxworth, 2014). Although there are limited reports on crowdfunding in food safety
98 projects, there are emerging sites for scientific projects in platforms such as Experiment.com,
99 Medstart.com, Petridish.org and SciFund Challenge Network (Kuo, 2016). These initiatives can link
100 donors i.e. public to visit scientific crowdfunding platforms and be reconnected to science (Schafer et
101 al., 2016). In other words, crowdfunded projects can be part of researchers' public engagement and
102 outreach efforts.

103

104 **Crowdsourcing and new product development (NPD)**

105 Food and drink start-ups are increasingly using the crowd and crowd-based platforms to leverage on
106 the crowd to decide, innovate and create new products (Palacios et al., 2016). One major problem with
107 newly introduced products is to anticipate what potential consumers actually need, i.e. which products
108 they are willing or likely to buy. The failure rate of newly introduced products is still as high as about
109 40% (Castellion and Markham 2013) and could in many cases also reach 70 to 80%. Food and beverage
110 firms that utilised crowd innovation to introduce new food products or beverages understood that
111 consumers' preferences (and their ideas) can distinguish between product success or failure. In addition
112 to developing new product ideas, crowd wisdom provides novel solutions, co-creation helps to develop

113 outcome-based services and to pursue collaborative ventures while crowdfunding helps to raise capital
114 (Palacios et al., 2016).

115

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

125

126 Insert Table 1 about here

127

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

133

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

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

152

153 **Crowdsourcing and open innovations (OI)**

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

160

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

172

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

183

184 The other alternative is to use external crowdsourcing. In this case, addressing all the issues and setting
185 the IPs where appropriate is probably the most difficult barrier in OI implementation and calls for
186 thinking 'outside the box' so that the collaboration can be initiated and the outcome benefits can be
187 shared. Although the '*Sharing Is Winning*' concept (Traitler and Saguy, 2009) was coined as an

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

212

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

219

220 Intermediary facilitators are service providers such as InnoCentive, Kickstarter, Seedr (funding platform
221 for entrepreneurs and investors) to connect the initiators or seekers with solvers. InnoCentive is an
222 example of a successful facilitating platform by utilizing crowdsourcing to develop solutions to scientific
223 problems. For instance, they launched a system linking outside experts to solve a pharmaceutical
224 problem and also offered a monetary reward to the solver (Allio, 2004). Typically, clients or firms will
225 seek out InnoCentive to post their projects on InnoCentive's platform, and a call for proposals/solutions

226 will be initiated to registered members (solvers) of InnoCentive. Winning solutions receive cash prizes
227 from the company seeking for solutions (InnoCentive 2016). It is obvious that crowdsourcing will be
228 useless without participation from the various experts.

229

230 Other intermediary platform includes Amazon Mechanical Turk (AMT) which provides crowdsourcing
231 service and permits researchers to pose tasks or questions which are then answered by a potential pool
232 of 500,000 participants (known as MTurk or Turkers). AMT is an example of a novel data collecting
233 platform and the Turkers complete short, "one-off" tasks for pay (Chandler and Kapelner, 2013). The
234 participants sourced via AMT are demographically diverse (e.g. 40% participants were from America,
235 33% from India and the rest from about 100 other countries; The Economist, 2012), age range of 20
236 – 40 years and the majority is females (Mason and Suri, 2012) when compared to 'standard' Internet
237 samples (Buhrmester et al., 2011). Other crowdsourcing service facilitators include oDesk, CrowdFlower
238 and Elance (The Economist, 2012).

239

240 **Crowdsourcing conceptualization on utilization for future food quality and safety**

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

254

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

261

262 **Crowdsourcing for future data and food safety solutions**

263 First and foremost, the crowd in food quality, safety and risk assessment should be defined. Food safety
264 experts are individuals with the (scientific) knowledge to potentially make informed sound judgements.
265 Food safety experts provide sound judgement about the likelihood that illness from a particular
266 pathogen is attributable to particular foods (Hoffmann et al., 2007). Harnessing data from experts can
267 be carried out via in-depth interviews, a formal written elicitation instrument (Hoffmann et al., 2007),
268 or utilizing a Delphi process in which a consensus of opinion among experts is obtained (De Boer et al.,
269 2005). Expert elicitation had been used as a method to crowdsource for possible solutions – albeit with
270 a smaller number of respondents. Food safety experts’ opinions are a valid approach especially when
271 there is insufficient or realistic data are not available (Pujol et al., 2015). Experts can provide both
272 short (i.e., food safety issues that require immediate action such as during microbiological outbreaks)
273 and long term food safety solutions (e.g. identification and preventive or reduction of contaminants
274 method). There is benefit in seeking experiential views on a topic or by soliciting for expert opinion.
275 This itself represents a fundamental challenge to overcome. Some of the questions that might arise
276 are, ‘How do we legitimate experience and scientific judgement and separate this from personal
277 opinion?’ Or, ‘how do we ensure experts only comment on the area they are experts in?’(Soon and
278 Baines, 2013). This can be addressed by first setting the selection/inclusion criteria of the experts
279 followed by the basis for the experts to make their judgements. Additionally, one can define the relevant
280 experience and professional legitimacy of respondents, then crowdsourcing for ideas, concepts and
281 solutions can be informative and creative. Via continuous research, development and sharing of
282 outputs, the expert group can provide feedback and scientific support to food authorities and private
283 food businesses. Meanwhile in the age of social media, the crowd representing the consumers can be
284 anyone with a computer, smartphone and Internet access (Rousseau, 2016). Consumers can review
285 restaurants, blog about their food experiences, publish recipes and photo sharing. Crowdsourcing
286 initiatives among consumers had been applied in the area of food safety particularly in foodborne illness
287 and outbreak surveillance (Hu et al., 2016; Kaufman et al., 2014; Nsoesie et al., 2015; Quade, 2016).
288 Kaufman et al. (2014) and Kaufman (2016) also tapped on the potential of sales data in the food supply
289 chain to identify contaminated food products. Prior to Kaufman’s initiatives, public health officials had
290 requested for permission and utilized customers’ loyalty card and warehouse membership to analyse
291 grocery purchases. The loyalty and membership cards provided valuable information whilst
292 investigating outbreaks (Barret et al., 2013; Gieraltowski et al., 2013). Meanwhile Sadilek (2016) utilized
293 Twitter’s data to capture the potential number of patrons who fell ill after eating at certain venues.
294 Quade (2016) and reports from Siegner (2015) demonstrated the effectiveness of the foodborne illness
295 reporting via the ‘Iwaspoisoned.com’ website. Nsoesie (2016) also utilize social media and business
296 review site such as Yelp.com to mine data on foodborne illness and outbreaks. The real time monitoring
297 and processing of crowd data helps to aid traditional surveillance and restaurant inspection systems
298 and the crowd are provided with an ‘outlet’ or platform to share their experiences of being sickened by
299 restaurant food. There is still untapped potential that can be harnessed from the crowd using social
300 media as the driving and reporting vehicle. Other potential areas that are worth investigating include

301 crowdvoting of cleanliness and hygiene of restaurants and effectiveness of allergen management and
302 communication provided by food services.

303

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

320

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

330

331 **Future crowdsourcing utilization: Shelf life and food inventory rotation**

332 Food product rotation is utilized to ensure that older stock is sold first. This routine is applied for a large
333 number of foods with shorter shelf life (e.g., frozen, refrigerated), but could be also implemented for
334 those food products with much longer shelf life (e.g., canned). Open dating is a common practice
335 and applies to all food products and drugs, and is an essential element achieving stock rotation at
336 retail, and simultaneously provides valuable and essential information to consumers as also required by
337 regulations. Open dating provides a simple communication tool, which may be based on product quality
338 and/or food safety as determined by the manufacturer. The variation in date labelling terms and usages

339 contributes to substantial misunderstanding by industry and consumers and leads to significant
340 unnecessary confusion, misapplication of limited resources and food losses and waste. Food waste is
341 estimated at 1/3 of the total global food production every year. The cost for food waste is estimated at
342 US\$ 680 billion in developed nations while developing countries were estimated at US\$ 310 billion. Most
343 of the losses in the developing countries occurred at the farm and during storage due to absence of
344 storage technologies and infrastructure. If temperature control cannot be assured throughout the food
345 supply chain, this defeats the reliance on open dating system such as "use by" or similar date labelling
346 as an indicator or guarantee for food safety (Newsome et al., 2014). The following section focus on
347 Time Temperature Indicators (TTI) and its potential usage in shelf life and food inventory rotation.
348 Although TTI per se is not a crowdsourcing method, but the data generated will benefit the users or
349 crowd throughout the food supply chain.

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

367
368 However, the wide spread of smartphones equipped with improved camera high quality and via the
369 utilization of crowdsourcing, big data and cloud computing open a completely new option that offers
370 entirely new tools and opportunities for the food manufactures to reconsider and manage their food
371 products rotation and shelf life consideration. The possibility for any consumer to scanned a simple TTI
372 equipped with an extended and unique universal product code (UPC) allowing full identification of each
373 and every package and monitoring the product quality by scanning the TTI and feeding the info into
374 the manufacture or a public database. The apps can then project on the screen the prediction utilized
375 by the manufacture shelf life model highlighting the product quality and other pertinent information.

376

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

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

401

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

409

410 TTI are essential and cardinal part of this future new application of combing crowdsourcing for
411 monitoring real time temperature data. TTI cost has been reduced significantly since their inception,
412 thus it is no longer a real unpassable barrier limiting their wide spread utilization. TTI ability to
413 accurately correlate with some quality attributes has been demonstrated for various applications
414 (Giannoglou et al., 2014). Yet, it is expected that the rich data provided through crowdsourcing will be

415 combined with advanced and sophisticated new approaches in utilizing machine learning, artificial
416 intelligence and other data mining techniques for the development of improved kinetic accurate models.
417

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

425

426 TTI Indicators utilization is just one key example among a plethora of new other possibilities and vast
427 potential offered by combining advanced sensing and smartphones. For instance, according to
428 Consumer Physics Inc. ([http://www.globes.co.il/en/article-consumer-physics-unveils-molecular-
429 sensing-smartphone-1001170338](http://www.globes.co.il/en/article-consumer-physics-unveils-molecular-sensing-smartphone-1001170338); accessed Jan. 7, 2017) the SCiO sensor (a miniature spectroscope
430 utilizing near-infrared light) was developed, and by teaming with China's Changhong Electric Co. and
431 US chipmaker Analog Devices Inc. unveiled the world's first molecular sensing smartphone. This
432 technology was reported to allow consumers for the first time to scan with their smartphones and
433 immediately receive actionable insights based on its underlying chemical composition, and their
434 molecular makeup. Hence, opening the possibility for consumers to analyse the properties of foods,
435 liquids, medication, body metrics, and others and probably address general issues related also to food
436 safety. The Changhong Company is also working to create a broad eco-system of mobile applications
437 that utilize the Consumer Physics Inc.'s SCiO sensor for a wide range of other uses. It is interesting to
438 note that the company is backed by Khosla Ventures and OurCrowd, among others. Also Consumer
439 Physics also raised \$3 million on Kickstarter – a crowdfund source. Consumer Physics Inc. believes that
440 the Changhong H2 phone will unleash a tsunami of other applications. Another example is C₂Sense's
441 sensor chip with 4 sensing elements on plastic, for detecting up to 4 compounds (e.g., ethylene for
442 fruit freshness, biogenic amines for meat/fish/poultry freshness, humidity and carbon dioxide)
443 simultaneously (<https://www.wired.com/2015/11/c2sense/>; accessed Jan. 7, 2017). C₂Sense's tiny chip
444 gives computers a sense of smell and in the future it could probably incorporated in a smartphone
445 application. The ability to sense ethylene at very low concentration by utilizing smartphones opens a
446 new avenue to reduce postharvest produce losses by managing stocks based on quality characteristic
447 parameters. Additional examples where Startups take bite out of food poisoning were described already
448 few years ago (Mims, 2014).

449

450 It should be however emphasized that verification of the information and in depth assessment of its
451 possible utilization, sensitivity, repeatability and accuracy should be tested and demonstrated under
452 real field of distribution and storage conditions before this technology could be commercialized and

453 fully utilized. Moreover, the utilization of social media carries also a heavy and increasing burden to
454 ensure that the system is not abused. Individuals and organizations have found ways to exploit these
455 platforms to spread misinformation, to attack and smear others, or to deceive and manipulate. The lack
456 of effective content verification systems on many of these platforms call for significant precaution to
457 ensure the accuracy and validity of the data collected. This issue needs to be fully considered and its
458 negative potential impact taken into consideration to avoid the harmful and damaging exploitations.

459

460 **Other possible benefits of crowdsourcing in food safety**

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

475

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

491 some of their aims such as promoting the use of innovative food safety technologies around the globe,
492 reduce foodborne diseases and outbreaks.

493

494 Incentive or Reward Mechanism

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

515

516 **Limitations of crowdsourcing in food safety**

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

529 crowd data is only useful if the feedback are taken into consideration and food businesses (and
530 authorities) took appropriate actions to improve their food safety problems.

531

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

551

552 **Conclusion**

553 There is potential for radical innovations and crowdsourcing in food safety and quality solutions.
554 Crowdsourcing leverages on crowd's intelligence and is capable of aggregating talent while reducing
555 time and costs. Crowdsourcing is only enabled through IT technology and requires continuous active
556 participation, user interactivity and transparent feedback. Targeting and motivating the right crowd can
557 assist food industry and authority in thinking in new trajectories. The above review clearly suggests
558 that crowdsourcing found a wide spectrum of applications in food innovations. It is however somewhat
559 limited in the area of food safety and quality. Crowdsourcing initiatives may be the means to harness
560 food safety solutions, predict foodborne disease outbreaks, identify contaminated food products and
561 improve hygiene, food safety and allergen management of food businesses. These data can be mined
562 and monitored in real time to take corrective or preventive actions if necessary. Similarly, there is
563 potential for crowdsourcing to be applied to complex food safety projects by engaging the crowd to
564 develop algorithms to improve big data analytics, identify models that can be applied to safety
565 assessments or to feed in data into risk assessments. Crowdsourcing may also be harnessed to reshape
566 inventory control by using advanced TTI and to reconnect public to science and to exhibit openness

567 and trust. Additional research is needed to facilitate the process especially on the collaboration between
568 industry and academia as well as other solution providers. It is also recommended that several studies
569 to be conducted in large food companies to highlight the specific benefits and best practices to enhance
570 the applicability of crowdsourcing.

571

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 943 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

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