Collaboration Networks for Information Empowerment of Food Consumers

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Abstract. The growing popularity of social networking platforms and recent advances in the internet of "things for food" open the way to conceive new information solutions to assist food consumers in their consumption activities. This paper deals with an egalitarian and bottom-up approach, where food consumers and stakeholders of the food supply chain interact to create and share valuable and reliable food information possibly coming from food instrumental measurements performed by consumers via smart food things. In particular, we propose a model of a collaborative network where members manage food information in a collective and distributed way (in terms of information generation, validation and delivery). Moreover, we highlight the outcome value of this new collaborative way of food information management under a consumer perspective.

Keywords: food information, food consumer's empowerment, Internet-of-food, collective awareness, consumer's perceived value

1. Introduction

Today's food consumers need more reliable food information to be aware of the consequences of choices that they make along their food consumption activities.

Food information is traditionally provided by food producers and/or distributors through mass media and labels on-package. This way of food information provision is producer-centered since it tends to satisfy companies marketing-related objective, rather than consumers' information needs.

On the other hand, food consumers are increasingly demanding high-quality, safe and healthy food [1], as they are more and more engaged in food related discussions in social networks with other consumers. Moreover, they interact with food related business (food producers, distributors, third parties) in loose, open and flexible ways, continuously searching for food information transparency along food supply chains.

Recently, the convergence between "Social Networking Platforms" and "Internet of things" opened the way for a new generation of context-aware systems [2]. The increasing availability of sensors and mobile devices represent the technological layer of a cyber-physical system that is able to provide context-based services to people in a smart environment [3].

New smart food applications and devices (e.g. “food scanner” or “food sniffer” for food analysis) suggest that the time is ripe to conceive new approaches to food information management that would empower consumers and be more responsive to their information needs.

The main challenge is to exploit the potential of collaboration through ICT networks to create a collective intelligence [4]. The basic assumption is that “a large number of individuals tied in a social network can provide more accurate answers to complex problems than a single individual or a small group” [5]. Collective knowledge represents an interesting issue that has been addressed in many research fields [6] [7]. The food sector represents another promising application field. In fact, technological advances in the so-called Internet of Food (IoF), make possible the development of a new generation of intelligent food services [8] able to provide context-based food information to consumers. In particular, IoF can be viewed as a network of food smart object augmented with sensing, computing (e.g. time-temperature indicators, sensors to detect food spoilage or bacterial infection, and so on), allowing a fast analysis of food items.

The consumer’s opportunity to access to more food information and the capability to exchange opinions and information with other consumers, are gradually shifting the balance of the competition. The chance to collect more information makes consumers more powerful, giving them the opportunity to be aware of their food-related choices. In particular, consumers’ information empowerment, i.e. the consumers’ improved capability to access, process and share food information [8], is gaining more and more importance. In fact, the possibility for consumers of “being in control” and “of being smarter” is crucial to carry out better food-related decisions during their food consumption activities.

This “consumer-centric” perspective of food information management (FIM) opens new ways in offering value to food consumers, driving some tech companies to enter the food information market at full steam. These companies offer the opportunity to exploit benefits new technologies, providing consumers to manage food information more responsive to their requests for information. In particular, these emerging trends make possible to design new collaboration networks where consumers and stakeholders of the food supply chain interact to create and share valuable and reliable food information.

This work aims to propose a model of a collaborative network where members manage food information in a collective and distributed way (in terms of information generation, validation and delivery), leveraging on open food data, IoF-based devices, and cloud/app-based solution. The model is a tool for researchers and practitioners, to explore a pathway towards collective food knowledge and information empowerment for a food consumer community.

Moreover, we propose an analysis of the outcome value of this new collaborative process of FIM under a consumer perspective that considers an evaluation of benefits and costs a consumer perceives as the result of the collaborative process when compared with other available FIM processes.

2. Modeling Food Information Empowerment Network

In a consumer-centric perspective of food information management, we envisage a new form of collaboration as letting consumers to be more aware during their food consumption activities. This collaboration can leverage on both potentialities of new smart-food technologies in determining food properties (from a physical, biochemical, and microbiological point of view), and a cooperative process in fostering collective food knowledge awareness. The rationale is to let a consumers' community have the opportunity to create and share reliable information about food.

In the emerging network, called Food Information Empowerment Network (FIEN), empowered food consumers collectively manage (generate, verify/validate, and distribute) information about several aspects (e.g. safety, quality) of food products and processes. In what follows, we view a FIEN as a collaboration network and we model it by describing its main endogenous dimensions, as suggested in [9].

2.1 Structural Dimension

This dimension deals with the composition of a FIEN in terms of its constituting elements and roles performed by these elements.
We identify the following actors and roles in a FIEN:

- *Simple Consumer (SC)*: a community member requesting for information about a specific food item performance [10].
- *Empowered consumer (EC)*: a community member who provides (in an implicit or explicit way) some measurements of food item characteristics by means of a smart food thing (i.e. a device able to catch some signals from food, like infrared emission, volatile compounds, etc.) and other descriptive data about a food item (e.g., date and place of production, batch number)
- *Information Broker (IB)*: an intermediate agent that processes requests from SCs, receives and controls data acquired by ECs and provide SCs with understandable (i.e. human-readable) food information.
- *Food Analyzer (FA):* an agent able to perform a diagnosis on a food item. It could be assisted by a software tool applying some intelligent methods (e.g. statistical methods, machine-learning based techniques) to determine food item characteristics.
- *Food Ledger Manager (FLM)*: a food database manager that receives and organizes data that comes from the Food Analyzer. Moreover, it provides results to query formulated by a Collective Challenge Solver.
- *Collective Challenge Solver (CCS)*: an agent playing the fundamental role in the collective process to generate reliable food information. It leverages on a food knowledge base and collectively reliable criteria to find the value of the food performance *p* shared by all food items that possess the same identity properties *i*.
- *Network Authority (NA)*: an entity that is in charge to manage the governance of the FIEN. Referring to the collaborative process, it sets and manages the criteria adopted by the Collective Challenge Solver to generate food information. These

criteria are based on a collective interpretation of food item characteristics, in order to determine to what extent information on food performances are reliable.

2.2 Functional Dimension

This dimension addresses the flows of operations (procedures, processes and methods) dealing with the operational phase of a FIEN. In particular, we focus on a collaborative process that allows the consumer community of a FIEN to create and share information on food performances related to some food items that belong to the same food class. The assumption that underpins the process model is that the reliability of food performance information can be derived from a collective interpretation of food characteristics information coming from measurements performed by smart food things.

The process consists of the following activities :

A.0.1 Collective Criteria Definition: *NA* defines the rules (e.g. methods, threshold values) for collective interpretation of food items' characteristics.

A.1.1 Request formulation: *SC* needs for reliable information about a specific performance *p* of a food item. *SC* makes a request *r(i, p)* to *IB*, where *i* is referred to a set of identity property values (food item descriptive data), while *p* represents a specific a performance SC wants to know (e.g. safety). *SC* transmits request data to *IB* through his/her own handheld device.

A. 1.2 Request Acquisition: *IB* verifies if the request can be instantly satisfied by querying a database containing data on challenges already solved. Otherwise, *IB* send a new challenge to the *CCS*.

A.1.3 Challenge formulation: Do food items with the same identity value *i* have the same value of performance *p*? *CCS* identifies food characteristics that are needed to determine *p*, by leveraging on a a food knowledge base. CCS formulates the query *q(i, c)* to *FLM* in order to retrieve values related to food items sharing the same identity value *i.*

A.1.4 Ledger Answer: *FLM* also provides results to the query *q(i, c)* formulated by *CCS*. Query results consist in a set of values of characteristics *c* for food items sharing the same identity value *i*;

A.1.5 Challenge Solution: *CCS* analyzes data provided by *FLM* and verifies whether the value of *p* can be calculated by leveraging on collectively reliable criteria established by the *NA*. If so, CCS determines *p*. Ther result is sent to FIB that is in charge to set-up the solution in a format understandable for *R*. Moreover, the result is stored in the solved challenge database. Otherwise, it notifies to *IB* that the challenge could not be resolved.

A.1.6 Results provision: *IB* receives challenge results from the CCS and provides results to *SC* in a human-readable form.

A.1.7 Results acquisition: *SC* receives Food information.

A.2.1 Food Data Acquisition: *EC* scans a food item by using his/her smart devices in order to acquire food properties data . In addition to these data, EB also provides descriptive data on food identity (*id*)

A.2.2 Food Data Validation: *IB* acquires and verifies food data as well as other interaction context data catched through environmental sensors. It passes the whole data to *FA*.

A.2.3 Food Data Analysis: *FA* performs a diagnosis of the food item in order to determine the value *c* of some food characteristics. In particular, it applies some intelligent methods (e.g statistical methods and machine learning-based approaches) able to deduce food characteristics. The pair (*id*, *c*) is sent to *FLM*.

A.2.4 Food Data Storaging: *FLM* collects and organizes data, namely the pair (*id*, *c*), in a database.

In figure 1, we provide a BPMN representation of the collaborative process, highlighting the contact points between consumers and the back-end process.

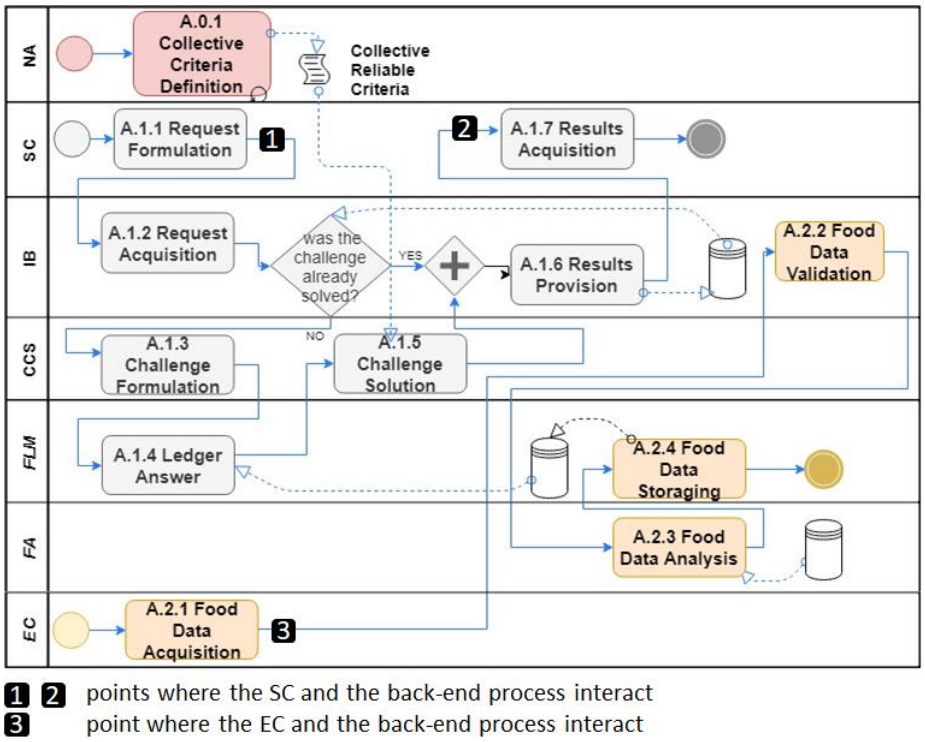

Figure 1. A BPMN representation of a collaborative process in a FIEN.

2.3 Componential Dimension

Intangible and tangible resources of a FIEN (e.g. information, knowledge, software, hardware) are taken into account by this dimension. In [11] a three-tier conceptual architecture for the FIEN has been proposed. This architecture consists of: 1) an interface layer that enables the user to entry, fetch and process food data; 2) a logic

tier for food data computation and analysis; and 3) a storage layer concerning with food information storage and retrieval. More details about a FIEN technological are provided in [11].

2.4 Behavioral Dimension

Along this dimension, the focus is onh policies, principles and governance rules influencing the behavior of the FIEN members. The *NA* has a crucial role in managing network members' behavior. In particular, the *NA* plays a dual role as:

- *technological intermediary*, whose role is to provide the ICT platform including, front-end and back-end software, security and communication;
- *guarantee authority*, that is responsible for the "ethical code" and "behavioural rules" for FIEN members. Moreover, it has an important role in attracting and selecting new members of the FIEN. It provides a comprehensive governance role, ensuring behavioural correctness of members' interactions in the FIEN.

In a FIEN, food information trustworthiness depends on the consumers' reliability on instrumental measurement, food data analysis techniques and security of information flows. The *NA* takes on the burden of building consumers' trust by defining the following aspects:

- *cooperation agreements*: the *NA* must guarantee the effectiveness and correctness of the measuring instruments adopted by the *ECs*. Therefore it should make collaboration agreements with smart things producers in order to define a set of certified and guaranteed FIEN platform tools.
- *obligatory behavior*: define rules and principles that are mandatory to be followed inside the FIEN. This comprises the definition of the collectively reliable criteria that are applicable to generate new food information, the definition of authorization profiles within the platform as well the definition of operational and managerial processes within the FIEN.
- *constraints and conditions*: ensuring transparency throughout the whole process of generation and sharing of food information and define the degree of restriction on the use of intellectual property of FIEN.

3. Consumers' Value of FIM

The multifaceted nature of food consumption makes the outcome of a FIM process extremely valuable to a consumer [1]. From a consumer perspective, the FIM outcome value is the ultimate trade-off between benefits and costs a consumer perceives as the result of his/her interaction with the FIM process and the involved community. Benefit/cost assessment varies from a consumer to another as it is affected by consumer's attributes (knowledge, food related values, experiences, attitudes). In what follows, we present a FIM outcome value framework consisting of the following factors and components:

Utility benefits. They refer to the overall utility of the information that a consumer acquires when interacting with a FIM process. Here, we refer to this utility as a

measure of the impact on consumer's food-related decision-making, brought about by the variation that occurs in consumer's assessment of a food product/service, because the interaction with the FIM process. Two entities play a crucial role in determining utility benefits:

a) *Content*: a set of information 'cues' that are exchanged between the consumer and the FIM process during the interaction. They may be declarative, as they describe and specify food quality attributes, or procedural, as they concern with food consumption activities. The main value factor is the **content relevance** that establishes how much impact the "what" is exchanged has on a consumer's food decision process. Content relevance sub factors are topicality, accuracy, depth, scope, clarity, organization, and format of the information exchanged [12].
b) *External Context:* a set of characteristics of the situation (food presence, place, time, food consumption activity, social relations, etc.) in which the consumer interacts with the FIM process. The main value factor is **situation relevance** that establishes how much impact the "how", "when", and "where" of the interaction has on a consumer's food decision process [8]. It may be defined as the extent to which information content is required to be specified to practical matters of the current situation.

Sociocultural benefits. They concern with the satisfaction of consumer's sociocultural needs through the consumer participation at the FIM community formed by other consumers and food chain stakeholders. Participation at the community brings a wealth of food cultural knowledge (including beliefs or practices), social norms, food literacy, as well as challenges that occur in consumer daily lives, e.g. credibility of food information sources. Main value factors are:

a) *Sociability* of the FIM community. It affects satisfaction of consumer needs of personal connectedness and relationships with other consumers and food chain stakeholders;
b) *Trustworthiness* of information sources in the FIM community. It affects consumer assessment of the reliability of the information content that FIM provides;
c) *Transparency* of the FIM process. It affects satisfaction of consumer needs of information empowerment and information asymmetry reduction [13].

Costs. They refer to consumer's physical and cognitive efforts that a consumer needs to interact with the FIM process or community, such as time, inconvenience and comprehension of food information. These efforts may be of two types:

- *Personal burden*. It refers to the amount of efforts a consumer has to put into interacting with a FIM process to get food information for personal use;
- *Collaborative burden*. It is the overload of efforts due to the participation to a collaborative FIM process.

In what follows, we apply the above framework to highlight main factors of the outcome value of FIM processes belonging to three broad classes: conventional FIM, social FIM, and collaborative FIM based on a FIEN.

In conventional FIM, consumers obtain food information through traditional channels like labels, radio, newspapers and television. The information content provided is:

– *massive and generic,* i.e., unable to meet specific consumer needs,

– *limited*, in terms of information amount and time-space availability,
– *biased*, as it is often directly provided by manufacturers or sellers who might emphasize some food properties, due to business oriented purposed.

As a result, consumers are sceptical, and they often ignore the information provided or perceive it as misleading. Moreover, they express concern about the information truthfulness and do not perceive any social benefits [14].

Social FIM uses internet-based technologies (the so-called web 2.0, including mobile apps and social media) for sharing information and overcoming some limitations of conventional channels [15][16]. In social FIM, consumers group together in communities around a collective goal and contribute to the creation and distribution of food information, but they rely on third parties (e.g., forum moderators, food bloggers, recommender systems) that control the FIM process [17]. Consumers may access:

– *a larger amount of information;*
– *tailored information,* according with consumer's profile and use*;*
– *in-time and in-place information.*

However, beyond these advantages, utility and sociocultural benefits remain limited by the lack of a verification and validation of the food information shared by consumers [18].

In collaborative FIEN-based FIM, social and IoF technologies enable a cooperative process focused on promoting collective food knowledge and awareness. Through such a process, food consumers may share food information originated from scientific instrument measurement of food properties. This type of FIM is still to come and it has been envisaged in this paper.

Even if it results in collaborative costs, as it engages a consumer in providing or validating information, collaborative FIEN-based FIM provides significant utility and social benefits. Food information based on scientific data, coming from in-context smart food things, could assure higher accuracy and depth, more correct scope, and specified for in-context food items. In addition to that, the collective validation process could enhance consumer trust in food information sources.

Table 1 summarizes significant characteristics affecting the consumer's value of the three types of FIM above discussed.

Table 1. FIM valuable components to assess the consumer's value of three types of FIM.

Valuable Components	Conventional FIM	Social-based FIM	Collaborative-based FIM
Content information	- static, limited in amount, massive, and generic	- consumer tailored	-consumer tailored -based on scientific data
Contextualized provision	- no contextualization	- in-time and in-place	- in-time and in-place - tailored on consumer's food activity - specific for in-context food items.
Community engagement	- consumer's information understanding and contextualizing	- seeking and evaluating channels and sources	- IoF device interaction - reduced cognitive effort for consumer's tailored

		-contextualization efforts - reduced cognitive effort for consumer's tailored information	information - reduced cognitive effort for context tailored information
Personal burden	- passive receptivity of contents. - information source limited to producers and distributors	- strengthening social relationships - information flows controlled by third parties - no verification process	- strengthening social relationships - consumer empowerment - information based on scientific evidences - information collectively validated
Collaborative burden	- no costs	- participation in community activities	- participation in providing and validating food data.

4. Conclusions

Conventional ways to provide food information have proved to be inadequate to satisfy today's food consumers' needs. In this direction, we have introduced a collaborative approach that offers to food consumers the opportunity to be more food aware and to carry-out more informed food-related decisions. This approach relies on a collaboration network where consumers manage food information in a collective and distributed way. The resulting collective food awareness would contribute to make vanish many "problems" linked-up with information asymmetries, driving consumers towards a greater consciousness about environmental, social and health-related issues.

Moreover, we highlighted the consumer's value of this new way of food information management by making a comparison with current ways of food information provision to consumers.

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