Information Technology as Enabler of Transparency in Food Supply Chains - An Empirical Study

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Abstract. Due to globalization, food supply chains are scattered around the globe. As a result, they become more complex and anonymous, potentially confusing customers of the food's origin and production conditions. In addition, due to higher living standards, consumers are demanding greater transparency in the food production process in terms of safety, quality, and sustainability. Simultaneously, technological developments have made various technologies available to track and provide information about food production to consumers at the physical Point of Sale (POS). However, current literature does not provide a comprehensive overview of technologies presenting transparent product information and guidelines about additional information consumers want to know. Therefore, the authors present a literature review of transparent product information and an outline of technologies to provide such information at the POS. Additionally, the authors present the results of an online survey highlighting the importance of individual transparent product information from a consumer point of view. Combining this information, the authors deduct guidelines on how to use technology to present transparent information to the consumer at the POS.

Keywords: Food supply chain · Transparency · Transparent product information

1 Introduction

Globalization permanently changed our economy, our lives, and consumer needs. Food travel distances have increased significantly while delivery times have shortened, resulting in a year-round season-independent food supply [1]. Meanwhile, consumers benefit from lower prices, higher quality, and a greater variety of food [2]. However, globalization has also increased the complexity and anonymity of food supply and value chains [3]. This unsettles consumers as it becomes difficult to understand the complex dynamics of today's food supply chains [1]. In addition, past food and livestock production related affairs, such as mad cow disease (BSE), swine fever, avian flu, and influenza, or the horsemeat scandal, have raised consumer awareness of food safety and drawn more

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attention to the production, processing, and distribution of our nutrition [4, 5]. Communicating the advantages of ecologically better food choices can positively influence consumers' purchase decisions [6]. Hence, global food supply chains are under increased pressure due to growing consumer demands [7] as their superior living standards imply that consumers are not only concerned about the taste but also about quality and authenticity [8]. Consumers have become more critical in recent years, demanding greater transparency in the food production process, wanting to be informed about the origins, processes of food procurement, the safety level, production methods, the use of pesticides, and the effects on environmental aspects [9]. Therefore, the traceability of food in global supply chains is of great importance [10]. However, current food supply chains show an information asymmetry towards the consumers, as the aspects of food safety and food quality are insufficiently transparent [11]. Though, for producers, traceability is also essential as it guarantees the quality of raw materials in the food chain, enables certification and approval of their products, and allows monitoring systems to be introduced [12]. Furthermore, with regard to corporate social responsibility, it is crucial to implement transparency in order to differentiate producers from other competitors [13]. Additionally, the sustainability of food supply chains is linked to social, ecological, and economic factors, which implies that increasing transparency and traceability of food supply chains has the potential to improve the social and environmental sustainability of food supplying companies' business practices [14].

Agrawal & Pal [15] emphasize that little is known about consumers' preferences regarding the provision of traceability information. New traceability technologies are available, and organizations are driven to use these technologies in order to offer additional information to their customers. However, the provision of large amounts of information is controversially discussed in literature as it can lead to information overload. Thus, Agrawal & Pal point out the necessity to separate between essential and non-essential information in order to enable an optimal exchange of information. In addition, the complexity of modern retail stores and personal time constraints force consumers to act economically and selective in their information intake [16]. However, this is countered by the fact that technological developments have made various technologies available that allow consumers to trace the path of food along the supply chain. Thus, making it easier for them to access product information providing transparency along the food supply chain (in the following: "transparent product information") and therefore supporting their decision-making process at the POS.

Previously published literature on transparent product information mainly focuses on the region of Asia (e.g. [16–19]). Additionally, a literature review done by Siddh et al. [20] illustrates that the majority of existing literature on food supply chain quality (from 1994–2016) concerns information, sustainability, and logistics management. However, only a minority of literature covers the management of food quality and safety [20]. With reference to this research gap, this study aims to find out more about consumers' preferences in German-speaking countries with regard to the use of technology at the POS and the most desired transparent product information.

Resulting from these problem fields, the authors derived the following research questions on food supply chain-related transparent product information.

RQ1: Which transparent product information can be provided according to previous research?

RQ2: Which transparent product information is most valuable for consumers?

RQ3: Which technology presenting transparent product information do consumers prefer?

The paper is structured in the following way: Following this introduction, the method section summarizes our literature review as well as the conducted survey. Subsequently, the results of the literature reviews and the survey are presented and discussed. The paper concludes with a summary of the results and provides implications for the field of HCI and opportunities for future work.

2 Method

This paper consists of a theoretical and an empirical part. The first research question is answered with a systematic literature review. Following the review, the paper presents an empirical investigation conducted in the form of an online survey. The results of the empirical part answer the second and third research questions. Combining the answers of all research questions, the authors deduct implications for companies and academics.

2.1 Literature Review

Various types of enabling technologies are available for the transparent presentation of supply chain information. For example, technologies for recording, storing, and transferring information (e.g., blockchains [21, 22]), linking between products and information (e.g., barcodes [23]), and enabling transparent product information to be displayed at the POS (e.g., smartphones [24]). However, due to the emerging trend of smart retail [25], a retail scenario that uses innovative technologies to enhance the shopping experience, we consider the POS a key element when providing transparent product information. This is because consumers often make unplanned purchases at the POS and thus can be influenced directly when making their purchase decision [25]. Therefore, this study focuses on technologies, which enable consumers to display information about the supply chain and the product directly in the store. From a typology of digital technology in stores, we considered the categories (i) *information/ product display technologies* and (ii) *information search technologies* and only included technologies that are used already to a certain extend (excluding technologies like *augmented reality* that few consumers have experience with) [26]:

- **Smartphones**: Smartphones are the most widely used personal mobile devices [27]. They are characterized by the fact that they are always at hand so that information can be received, recorded, or sent at any time. In retail stores, smartphones can be used to scan products and display associated information [24].
- **Smart Displays**: Smart displays are digital screens that display various content types among animated or interactive elements. In retail stores, smart displays can be placed above shelves to display additional information about products on the shelf [28].

- **Interactive In-Store Kiosks/Terminals**: In-store kiosk systems, also known as terminals, are free-standing, physical information and service units with touch-screen monitors. In-store kiosks provide an interface that allows users to interactively call up specific information, such as in-store navigation, purchase suggestions, or additional product characteristics [26].
- **Smart Shopping Carts**: Intelligent shopping carts, also known as smart trolleys or smart shopping carts, are equipped with scanners (e.g., hand scanners) and a screen (e.g., tablet). This provides additional services like scanning products to access further information or self-service payment [29].

The literature review to identify transparent product information elements, to be displayed via the above-listed technologies, was carried out from March to April 2020 in various online databases. It comprised the four steps shown in Fig. 1.

Step 1: In the first step, we used a predefined set of keywords on a predefined set of databases to identify relevant scientific papers and industry case studies. The following keywords were used to identify relevant papers and industry case studies: transparency OR traceability AND food AND "supply chain" AND "consumer preferences" AND sustainability OR quality. These keywords were used as search strings in the following databases: AIS, EBSCO Business Source Premier, Emerald Insight, Google Scholar, IEEE Xplore, Science Direct, Taylor and Francis, Web of Science, Wiley, WISO. This led to 15 articles and 7 industry case studies.

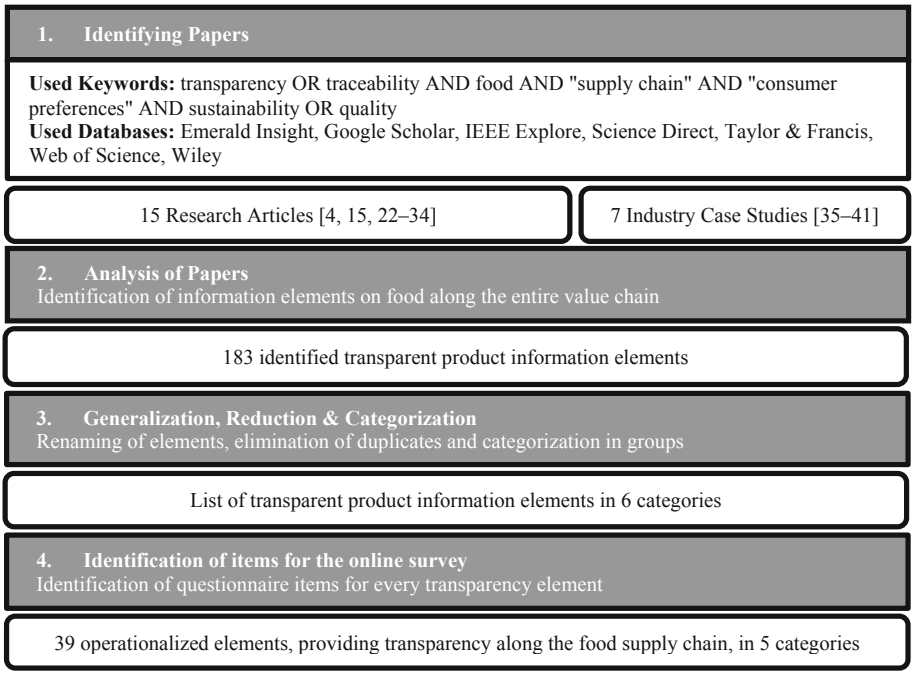

Fig. 1. Four steps of the literature review

Step 2: In the second step, we deducted relevant transparent product information elements from the papers and industry case studies. The identified papers also included studies that conducted literature reviews to identify characteristics that customers consider essential for assessing products and their supply chain (e.g. [15, 30, 31]). Thus, by analyzing these papers, 183 transparent product information elements could be identified. This included duplicate entries because numerous elements have been mentioned in multiple papers.

Step 3: Since transparent product information elements are named differently in the identified scientific papers and industry case studies, in a third step, we conducted a summarizing qualitative content analysis to consolidate them [32]. The elements were consolidated by renaming elements that were named differently but had the same meaning (generalization) and eliminating duplicate elements that resulted from this generalization process (reduction). This procedure resulted in a list of transparent product information elements that were further categorized (categorization) into the following groups (i) origin, (ii) freshness, (iii) cultivation & production methods, (iv) transport, (v) sustainability, and (vi) product properties. These categories facilitated the survey and analysis.

Step 4: In a final step, the identified transparent product information elements were operationalized for the online survey by generating items based on other questionnaires in the literature. Since the elements in the category (vi) product properties (e.g., price, packaging, brand, etc.) did not describe the characteristics of the food supply chain, this category was omitted. Consequently, this process led to 39 transparent product information items in five categories that were operationalized via survey items.

2.2 Online Survey

An empirical investigation was conducted using an online survey in Germany, Austria, and Switzerland between June 2, 2020, and June 20, 2020. To ensure comprehensiveness and understandability of the survey, and that no misunderstandings arise, a pretest with 15 persons was conducted. The survey aims to determine which transparent product information elements are most valuable for consumers and which technology presenting transparent product information consumers prefer. The elements identified in the literature review were used in the questionnaire to determine the elements of interest regarding product information transparency.

As a result of the survey, the elements are ranked based on the respondents' ranking, which elements they perceive as most valuable when shopping for groceries at the POS. Further, the survey provides results on the preference among four different technologies presenting transparent product information. The survey consists of 37 questions and is divided into six sections containing 32 closed or hybrid questions and 5 open questions. The outline of the survey is displayed in Table 1.

As suggested by Rugel et al. [18], nominally scaled questions, where there is concern that the order in which the answers are given will influence voting behavior, answer options were randomized. For questions with ordinally scaled answer options, the natural

Table 1. Survey outline

Question	Source
Shopping Behavior	
Who is the person responsible for grocery shopping in your household?	[36]
For how many persons do you go grocery shopping?	
How would you describe your household?	
How often do you go grocery shopping?	[37]
In which shopping location do you do grocery shopping?	[38]
Product Information	
How important are these product characteristics for you when shopping for groceries?	SD
How important are these criteria when shopping for groceries?	
Please rank the importance of these product information when doing grocery shopping	
Are you satisfied with the product information currently available on the packaging/shelf?	[37]
Which product information are missing regarding origin, ingredients, production, transport, or sustainability?	
Food Security	
Which topics concern you the most when thinking about groceries?	[39]
What is your opinion regarding food safety?	
Interest in transparency information	
Which of the following information regarding the origin of food is interesting for you?	SDI [37]
Which of the following information regarding the freshness of food is interesting for you?	
Which of the following information regarding cultivation and production methods of food is interesting for you?	
Which of the following information regarding the transport of food is interesting for you?	
Which of the following information regarding sustainability when buying food is interesting for you?	
Transparency Usage	
Have you used the following transparency applications?	SD
How satisfied are you with used transparency applications?	
Why are you dissatisfied with the used transparency application?	

(*continued*)

Table 1. (*continued*)

Question	Source
Where would you like to see these information regarding food to be displayed?	
How would you prefer food information to be displayed on a smartphone?	
What would be the preferred design of a smartphone food transparency application for you?	
In which buying phase would you like to receive transparent product information?	
For which food product groups would you like to receive transparent product information?	SDI [40]
In general, I am interested in the transparent product information for food	SD
In general, I interest in a technological application providing traceability information	
Why are you not interested in a technological application providing traceability information	
I would use a technological application providing traceability information	
Why would you not use a technological application providing traceability information?	
Would you prefer buying a product that could be traced back to where it was produced?	
Demographics	
Gender	SDI [41]
Age	
In which country do you live?	SD
Choose the answer which describes your occupation situation best	SDI [41]
Please choose your highest educational level	
What is your net household income?	[38]

SD (Self-developed, based on the literature review), SDI (Self-developed but inspired by [Source])
All questions were translated from German

ordering of the response options remained. However, for ordinally scaled questions, the individual items' order was sorted randomly to avoid adverse effects on voting behavior [33]. The online survey was distributed by the platform Surveycircle, which currently represents the largest community for online research on whose website one's own survey can be published in order to attract survey participants [34]. Pictures accompanied questions on technology preference to give respondents a visual impression of the four selected technologies, as depicted in Fig. 2.

The complete survey can be accessed at https://doi.org/10.5281/zenodo.4438820 [35]. The survey data are analyzed with the help of MS Excel and the statistical program SPSS.

Fig. 2. Visualization of technologies in the online questionnaire

2.3 Survey Sample

After the survey collection phase was completed, 578 entries could be recorded. Before the results were evaluated, data cleaning and error checking was carried out. In total, 174 entries were not completed in full or were aborted, and three entries were excluded because of their participation from countries not being Germany, Austria, or Switzerland, resulting in 401 complete data records used for the evaluation.

Looking at the descriptive statistics, Table 2 shows the demographics of the sample, and Table 3 provides insights into the sample's shopping behavior. On average, the respondents prefer to go to 2.8 shopping places to do their grocery shopping. As the separate analysis of Austria, Germany, and Switzerland only yielded minimal deviations, a separate evaluation for each country was not carried out, and all countries were included in a single analysis.

Table 2. Demographics

	N	%		N	%
Age (M_{age}= *31.93 years,* σ = *12.927*)			**Education**		
Less than 25 years	172	42.9%	University Degree	163	40.6%
25–35 years	131	32.7%	Baccalaureate	144	35.9%
36–50 years	39	9.7%	High School	46	11.5%
Above 50	59	14.7%	Apprenticeship	36	9.0%
			Other	7	1.7%
Gender					
Male	141	35.2%	**Occupation**		
Female	260	64.8%	Employed	204	50.9%
			Student	154	38.4%
Nationality			Unemployed	18	4.5%
Austria	297	74.1%	In retirement	12	3.0%
Germany	97	24.2%	"Other"	6	1.5%
Switzerland	7	1.7%	Pupils	5	1.2%
			In apprenticeship	2	0.5%
Household					
Couple without children	134	33.4%	**Net household income (per month in EUR)**		
Single living with parents	77	19.2%	<2,400	176	43.9%
Single household	67	16.7%	> 2,400 and <3,799	135	33.7%
Couple with children	62	15.5%	>4,800	49	12.2%
Other	47	11.7%	No Answer	41	10.2%
Single with children	14	3.5%			
Total	401	100%		401	100%

Table 3. Shopping behavior

	N	%		N	%
Grocery shopping for			**Grocery Shopping Responsibility**		
1 person	75	18.7%	With household members	230	57.4%
2 persons	171	42.6%	Alone	119	29.7%
3–4 persons	126	31.4%	Household members	49	12.2%
5 persons	25	6.2%	Other person	3	0.7%
>5 persons	4	1.0%			
			Preferred Location to shop groceries		
Frequency of grocery shopping per week			Supermarket	134	33.5%
1	128	31.9%	Discount Store	86	21.5%
2–3	238	59.4%	Specialty Store	52	13.1%
4–5	26	6.5%	Drugstore	46	11.5%
6–7	9	2.2%	Farmer / Producer	34	8.5%
			Farmers Market	26	6.5%
			Organic Food Store	22	5.7%
			Other	1	0.3%
Total	401	100%		401	100%

3 Results

The following section presents the results of the conducted survey and its underlying literature review.

3.1 Literature Review

The result of the literature analysis process is shown in Table 4. It provides a list of transparent product information items that can be used for decision-making when selecting

Table 4. Ranking of transparency elements by importance

Category	Transparency element	L	Mean	Median	ER
Sustainability (M = 5.34)	**Species appropriate animal husbandry**		**6,10**	**7**	**3**
	Recycling (recyclability of the packaging)	x	5,57	6	8
	Workers' rights & working conditions, child labor, etc		**5,55**	**6**	**9**
	Environmentally-friendly production impact		**5,41**	**6**	**10**
	Labels (e.g. fair trade, organic)	x	5,27	6	12
	Amount of packaging, generated waste		4,97	5	16
	CO2 footprint of the food (production + transport)		4,97	5	17
	Resources used (e.g., water consumption)		4,85	5	23
Cultivation and Production methods (M = 5.26)	Type of animal husbandry (free-range/stable/etc.)	x	6,17	7	2
	Pesticide use (sprayed) on fruits and vegetables		**5,82**	**6**	**6**
	Organic/conventional farming	x	5,65	6	7
	Type of farming method for fish	x	5,20	6	13
	Farming method (greenhouse/field/etc.)		4,86	5	22
	Type of fishing method (trawl/fishing/etc.)	x	4,63	5	29
	Processing steps of the food		4,52	5	31
Freshness (M = 5.06)	Best before date	x	5,91	7	5

(*continued*)

Table 4. (*continued*)

Category	Transparency element	L	Mean	Median	ER
	Slaughter date for meat		4,98	5	15
	Packing date of food		4,95	5	18
	Harvest/picking date for fruit & vegetables		4,89	5	19
	Catch date for fish		4,87	5	21
	Laying date for eggs		4,76	5	26
Transport (M = 4.54)	Distance from farm field to the shelf in km		4,79	5	25
	Duration from farm field to shelf		4,68	5	27
	Tracking of compliance with the cold chain		4,65	5	28
	CO2 consumption due to transport		4,56	5	30
	All means of transport used (plane/ship, truck/rail/etc.)		4,29	4	32
	Primary means of transport used		4,25	4	33
Origin (M = 4.40)	Country of origin for fruit & vegetables	x	6,24	7	1
	Country of origin for meat	x	6,06	7	4
	Country of aquaculture/fishing area for fish	x	5,33	6	11
	Food inspection protocol		**5,01**	**5**	**14**
	Exact place of origin for fruits & vegetables		4,87	5	20
	Exact place of origin for fish	x	4,79	5	24
	Additional information on species/fish		3,97	4	34
	Name of the producer(s)	x	3,84	4	35
	Address of the producer(s)	x	3,54	4	36
	Name of the supplier(s)		3,24	3	37
	Address of the supplier(s)		3,01	3	38
	Additional information about the company		2,94	3	39

***ER = Element Rank**
***L = Mostly labelled on Packaging**

food (used research articles: [4, 15, 17, 30, 31, 37, 39, 42–49]; used industry case studies: [50–56]).

3.2 Transparent Product Information Survey

Resulting from the survey responses, Table 4 also provides the ranking of the importance of the individual transparent product information items and their corresponding categories (sorted by the mean ranking per category).

It becomes apparent that the five most important transparency elements (see Element Rank (ER) 1–5 in Table 4) are "Country of origin for fruit and vegetables" followed by the "Type of animal husbandry", the "Species-appropriate animal husbandry", and "Country of origin for meat". In addition, essential for respondents is the "Best-before date" and the "Pesticide use in fruits and vegetables". It has to be noted that grocery products in the European Union already require several of these transparency elements to be displayed on the product packaging (e.g., free-range husbandry of eggs) or signs at the product shelf (e.g., Bananas from Brasil) [57].

When focusing on additional product information that is typically not (yet) available at the POS but could be provided by an additional information source, such as technology, the five most important transparency elements are the following (highlighted with bold letters in Table 4):

1. Species appropriate animal husbandry
2. Pesticide use (sprayed) on fruits and vegetables
3. Workers' rights & working conditions, child labor, etc.
4. Environmentally-friendly production impact
5. Food inspection protocol

Additionally, we surveyed the participants to determine which technological application is preferred for providing transparent product information. The "Smart Display" was selected by 32% of respondents, followed by the "Smart Shopping Cart" (30.6%), the user's self-owned smartphone (29.3%), and the Terminal (8%). Multiple answers were possible for this question. On average, one person selected 1.6 answer options for this question.

4 Discussion

The online ranking results on the participants' preferred technology choice show that customers may value smartphones, smart displays, and smart shopping carts higher to retrieve the product information of interest than a stationary terminal. One possible reason for this low ranking might be that specific product information should be available at the moment of decision-making. Therefore, it might be advisable for retailers to consider that grocery shoppers prefer technology, which allows retrieving additional product information and does not force a specific movement through the store. The difference between the three most preferred technology options is less than 3%. Therefore, it could be beneficial for retailers to design a type of cross-device application providing

additional transparent product information to consumers, which is not yet provided on product labels or signs at the POS. Among the three preferred options, smartphones represent the most cost-efficient and scalable option. As of its customer-owned nature, retailers would not need to invest in additional technological infrastructure among the entire store landscape.

Based on the conducted literature review, we identified 38 transparency elements that potentially lead to improved transparency of the food supply chain, of which 13 are already commonly available on the products packaging, labels, or signs at the POS. From the quantitative survey results, four of the five most essential transparency elements are already provided at the POS in German-speaking countries, which refer to the country of origin of fruits, vegetables, and meat, as well as the type of animal husbandry, and the expiration date. Looking at the most important transparency elements which are not (yet) available at the POS, consumers request more information on the appropriateness of animal husbandry (ER 3), if pesticides have been used on organic food (ER 6), the workers' rights and working conditions (ER 9), whether the production had an environmentally-friendly production impact (ER 10), and would like to see a proof in the form of a food inspection protocol (ER 14). These five highly preferred transparency elements mainly refer to the category of sustainability (ER 3, 9, 10), as well as to cultivation and production methods (ER 6) and origin (ER 14). These results support current research on consumers' increasing awareness of sustainable and "green" consumption choices [58]. In contrast to the ongoing discussion in research and industry [e.g., 59], the ranking of product information preferences in this study revealed that information transparency of the category "Transport", for example, the distance and the related cause of CO2 emissions, are less important to consumers.

The study has some research limitations that can be venues for future research. The sample consists of young adults perceiving higher education and includes more female participants than the average population, limiting this study's generalizability. Moreover, a person's fundamental principles and values are strongly related to product information seeking, which were not enquired in the present work. For instance, customers who value tradition, security, and conformity are less susceptible to consider sustainability aspects in their purchase decision [58]. Moreover, the study was carried out in German-speaking countries only. Future research could investigate product transparency in other countries, where more/less additional product information is available at the POS and where value orientations differ on a societal level [58]. An additional approach is to investigate the differences in product information of low and high involvement products and the customer's trust in the displayed information [6].

Building on this study results, researchers could focus on one specific information type (e.g., environmentally-friendly production impact) and investigate the consumer's technology preference. Therefore, researchers could address how certain product information is linked to technology preferences and vice versa. Moreover, the study design could be enriched by presenting the respective technology with various media types (e.g., a video of various technologies in use). Finally, the study could also be conducted in a lab environment or in the field where users can directly interact with the technology.

As the presented results focus on comparing general preferences for different customer-facing in-store technologies, it calls for a more in-depth view of User Experience (UX) abilities and the technologies' actual usage. Forthcoming studies could investigate the influence of an application providing transparent product information on consumer adoption and behavior. Additionally, various design and UX factors of a cross-device application might play a crucial role in the fast-paced food shopping environment to ensure a strong and positive impact on consumer behavior. New and innovative in-store technologies could also play a crucial role at the POS. For instance, a head-mounted mixed-reality shopping device (e.g., Microsoft HoloLens) that can merge pervasive, computer-generated transparency product information (virtual objects) into the real world could play a crucial role in future shopping scenarios [60].

5 Conclusion

Customers demand greater transparency and traceability about the food products they are purchasing and consuming [4, 5]. Industry follows this upward trend by increasingly providing more transparent information on product packing, labels, and signs at the physical POS.

In this paper, we examined this topic by (RQ1) identifying transparent product information from the literature and conducting a survey to investigate (RQ2) which transparent product information are most valuable for consumers and (RQ3) which technology to present this information consumers prefer. In the systematic literature review we found 15 scientific papers and seven industry case studies and identified 39 transparent product information elements in the categories (i) origin, (ii) freshness, (iii) cultivation & production methods, (iv) transport, and (v) sustainability. We used these 39 transparent product information elements to design a survey to answer research questions RQ2 and RQ3.

Results show that the most important transparent product information are already present on the packaging of most products or shelves in the region of the survey (Germany, Austria, Switzerland). Further important but currently not available transparent product information should be provided via additional technology: (i) species-appropriate animal husbandry, (ii) pesticide use (sprayed) on fruits and vegetables, (iii) workers' rights & working conditions, child labor, etc., (iv) environmentally-friendly production impact, and (v) food inspection protocol.

The survey also revealed that consumers do not have a preferred technology to display this information. Smart displays (32.0%), smart shopping carts (30.6%), and smartphones (29.3%) had similar results. Only terminals (8%) can be considered as an inept technology.

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