TagItSmart
Smart tags driven service platform for enabling ecosystems of connected objects

Grant agreement 688061

Validation, impact and dissemination activities

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Contents

Section 1 - Introduction ***4***

Section 2 - Preparation of Trial ***5***

2.1 Hardware and Software Preparation **5**

Section 3 - Data Management Frontend ***9***

3.1 Frameworks **9**

3.2 User Interfaces, Dashboard view **9**

Section 4 - Execution of the trial ***13***

4.1 User Experience **17**

4.2 Microbiological laboratory validation **19**

Section 5 - Impact and Dissemination ***21***

5.1 Dissemination activities during the project **21**

5.2 Impact and Go-to-market strategy **22**

Section 6 - Conclusions ***24***

Document history

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List of Figures

Figure 1: Univerexport departmental store at Novi Sad, Serbia.
Figure 2: Picture of tsenso sensor and mobile application.
Figure 3: Implemented system architecture during FreshTag project.
Figure 4: Data pipeline.
Figure 5: Dashboard of products under management.
Figure 6: Dashboard of sensors under management.
Figure 7: Dashboard of monitoring under management (filters: “active” and “Transport” set).
Figure 8: Detail view of a specific monitoring, including sensor details and data export.
Figure 9: Access to the FreshTag scanner for consumers (left) and registered users (right).
Figure 11: Picture of a product attached with tsenso sensor and FreshIndex QR code.
Figure 12: Detailed information on product data, accessible only to registered customers.
Figure 13: Picture of TagItSmart Counter at Univerexport.
Figure 14: Picture of meat packages placing at counter and attaching tsenso sensors.
Figure 15: Picture of TagItSmart mobile application in action.
Figure 16: Picture of meat packages bring to Stuttgart for lab testing.

Section 1 - Introduction

Expiry dates, as used in the food industry today, are important achievements in providing food safety, but they are also subject to considerable criticism. Many consumers consider the printed expiry dates as a fixed limit and throw away their food on the day of expiry even though it might still be good to eat. To overcome this undesirable situation, we propose a dynamic shelf-life indicator, the Fresh Index, calculated on the storage and handling conditions for each individual perishable product unit.

This storage data is to be recorded from the moment of production all along the supply chain to the retail store and potentially even including the fridge of the consumer. In contrast to other approaches that failed due to high operating costs, FreshTag makes use of innovative low-cost SmartTags of the TagItSmart platform and a comparably small number of tsenso Bluetooth low energy temperature loggers. By combining the product and storage data using predictive food modelling and risk assessment, the remaining product shelf life can be calculated. Validation schemes to prevent data manipulation and fraud will be implemented.

The development of the FreshTag project is split into three work packages:

- Requirement analysis, architectural design and implementation
- Algorithms for Food Modelling and Fresh Index calculation
- Concept validation and dissemination (this deliverable)

The work targets to find the optimum process to predict the dynamic shelf life providing stringent uncertainty handling, while at the same time eliminating any error prone manual handling steps and minimizing the operating costs. We will implement the data architecture and algorithms in a module connected to the TagItSmart Platform, using dynamic real-time temperature data and IoT tags and cloud computing technologies. The module was validated by a real-life field trial with independent measurements of certified food safety laboratories. This work, based on smart tags and intelligent computer prediction models can be the basis for a new, smarter approach to optimize EU food safety processes and has a clear potential to shape consumer demands according to product availability by dynamic pricing.

In this deliverable the results of the trial in Novi-Sad, Serbia are presented. The trail was executed along the supply chain of Univerexport and in collaboration with DunavNET. The calculations of the FreshTag module during the trial have been cross-checked by microbiological analyses of samples of the trail and by storage measurements done by an independent, accredited food lab in Germany.

Section 2 - Preparation of Trial

The concept of field trials is a certain stage in the product development, when the product under development is tested by users under 'real life' conditions. Based on the positive results of our food modelling, see Deliverable_D2, the FreshTag module has reached the maturity for this stage. The product and the field trial setting are designed to be as close as possible to actual usage. The aim of the trail is on the one side to prove its reliable functionality under real conditions. On the other side, we conducted interviews with users in order to plot the customer experiences in using our product. The trial happened in the city of Novi Sad, Serbia at one of the departmental stores of Univerexport.

Figure 1 Univerexport departmental store at Novi-Sad, Serbia.

2.1 Hardware and Software Preparation

The reliable functionality of the FreshTag module depends on reliable temperature sensor data loggers that can be attached to the meat package during transport. The loggers collect the temperature on regular intervals without any break. The FreshTag module can operate with temperature data loggers of any other manufacturer. For the trail, we used our own tsenso Bluetooth Low Energy (BLE) loggers, as the offer a very good price-value ratio.

During the trail, one sensor was attached to a single product unit. In the case of an industrial roll-out of the solution, one data logger will be used to monitor a full pallet of products or a refrigeration unit. This difference of set-up in the trail is due to the fact that the trail was done in parallel with a second TagItSmart dynamic pricing trail, for with also one third party module was attached to one product as well.

In case of a larger roll-out the combination of BLE loggers with more long-range sensors, such as the LORAwan protocol is advised to further reduce costs.

During this project, the software development was aligned with the team of DunavNET in Novi Sad so that the FreshIndex calculated by our software can be shared well on time with the TagItSmart application.

Six tsenso temperature data loggers were prepared for the trial in Stuttgart and calibrated properly with the mobile application on Android phone.

Figure 2: Picture of tsenso sensor and mobile application

2.1.1 System architecture

The system architecture is sketched in Figure 3. The frontend related tasks are managed by a designated Service Module (SER). The incoming sensor, product and logistics data is received by a context broker module inside the SER. The SER is also responsible for updating future web and mobile applications, such as a business intelligence toolbox and the internal applications for quality assurance using data science. The SER module shows excellent scalability, capable of handling up to 1 million users and 100 million products simultaneously.

The Data Module performs the initial data quality checks and links the respective sensor and logistic data to the corresponding product unit. The in-depth analysis of the food freshness will be performed by the Simulation Module (SM).

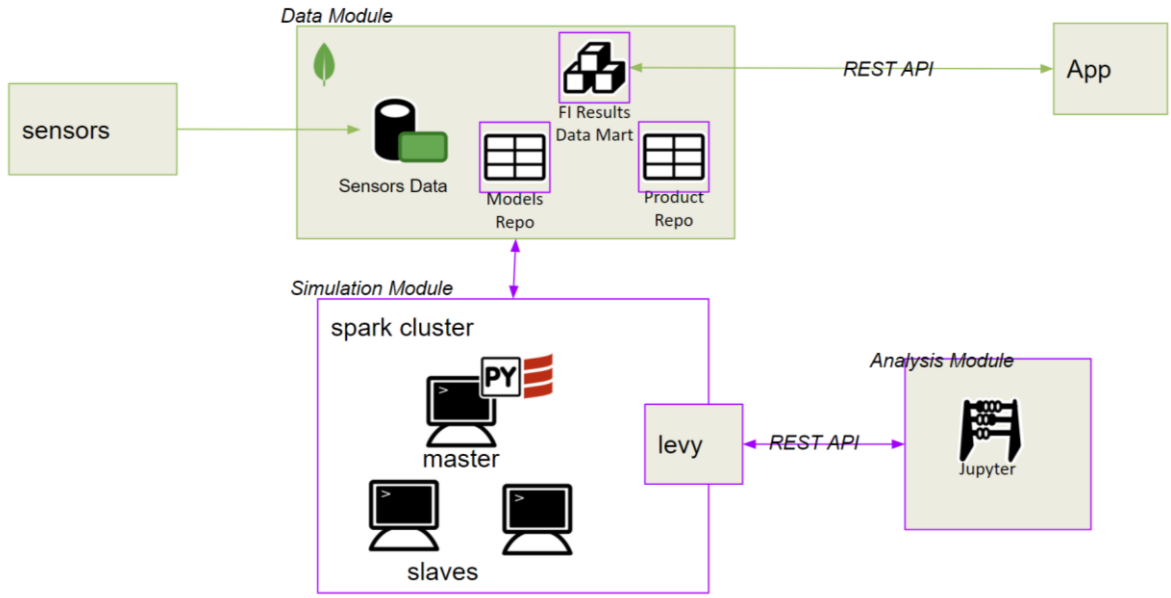

Figure 3: Implemented system architecture during FreshTag project

The data pipeline, see figure 4, is defined by:

a) Data ingestion managed by the SER with a focus on high input/output availability.
b) Data curation managed by the DM with a focus on data clustering for the reduction of persistent storage input and fingerprinting to identify fraudulent data
c) Data provisioning, in the concept of a data market, managed by the SER to assure high availability and also fast reactivity on customer requests via the web and mobile applications

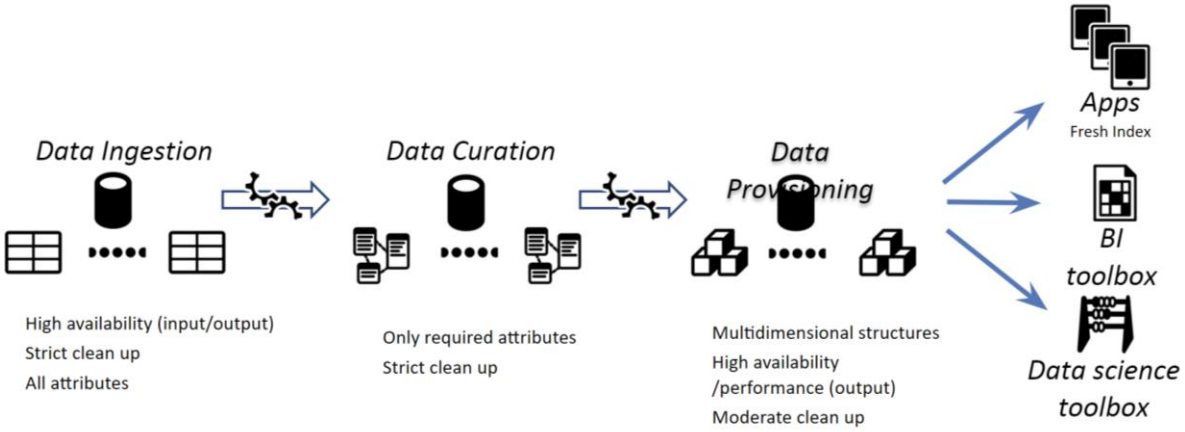

Figure 4: Data pipeline

2.1.2 Simulation module architecture

In alignment with the project coordinator DunavNET the implementation of the system focuses on the food safety and thus follows a simplified system architecture. The maximum tolerated calculation time for the FreshIndex query is 1 sec.

2.1.3 Internal API interfaces

In internal interface between the Data Module (DM) and the Simulation Module (SM) is described in detail in deliverable FreshTag_D1 *Definition of IT architecture and Implementation.*

2.1.4 External API reference

An API has been developed while closely working with the team of DunavNET. The structure of API is as shown below in the table. This service provides the FreshIndex saved in the database of tsenso for the QR Code of TagItSmart sent via URL. The result will be shown on the mobile application of TagItSmart.

URL	**https://dev.tsenso.com/api/freshindex/TagITSmartQRCode**
Method	GET
Header	Content-type: application/json

Results Structure

Key	Type	Required	Ver.	Descriptions
Type	String	Yes	1.0	Type of data, e.g. “version=1”
FreshIndex	String	Yes	1.0	FreshIndex value of last measurement
Return Result	JSON Array	Yes	1.0	Internal data of simulation module returned as JSON Array

2.1.5 Licensing

The external API, see section above gives access to the calculation algorithm of the simulation module, see Figure 4. Calling the API will trigger the calculation of the growth of microbial spoilage in the product with the most recent data that is available in the Data Module. The current implementation of the API returns the coarse-grained FreshIndex as the result. On customer request it is possible also to return the microbial bacterial count in colony forming units CFU.

Short description	API reference	License	Comments
Call the calculation of the growth of spoilage using the most recent data available at the time of the call	https://dev.tsenso.com/api/freshindex/TagITSmartQRCode/SensorID	Property module with open API,	Calling the FreshTag API is free of cost. The sensors can be bought or rented. On customer request also 3rd party sensors can be added to the Data module

tsenso is currently looking for an industry partner to jointly co-develop the FreshTag functionality to a reliable, scalable solution for the food industry. The module can be provided on-premise or as hosted cloud solution.

Section 3 - Data Management Frontend

3.1 Frameworks

As basic computing engine, we have chosen the Apache Spark framework, as this is an open-source cluster-computing framework. Originally developed at the University of California, Berkeley's AMPLab, the Spark codebase was later donated to the Apache Software Foundation, which has maintained it since. Spark provides an interface for programming entire clusters with implicit data parallelism and fault tolerance.[1]

As programming language, we have chosen Scala. Scala has its name from the words scalable and language, signifying that it is designed to grow with the demands of its users.[2] Skala
Like Java, Scala is object-oriented, and uses a curly-brace syntax reminiscent of the C programming language. Unlike Java, Scala has many features of functional programming languages like Scheme, Standard ML and Haskell, including currying, type inference, immutability, lazy evaluation, and pattern matching.

The system infrastructure is hosted on cloud instances by Amazon Web Service (AWS), which has shown great stability and a good price-value ratio. We are aware that AWS is disfavored by most retailers, due to the AmazonFresh activities. As the system is built on kubernetes, a potentially required shift to another cloud platform or the on-premise installation on the cloud of a retailer can be realized with moderate effort.

3.2 User Interfaces, Dashboard view

The tsenso solution provides the needed usability for the solution to be used in an industrial environment, where one quality official needs to be able to identify potential problems with a single click on the management dashboard.

The professional user has access to the application data by three data structures

- Products, storing all the product related data
- Sensors, managing the sensor configurations
- Monitoring, the measurement data of a specific sensors linked to a specific product for a specific start and end time.

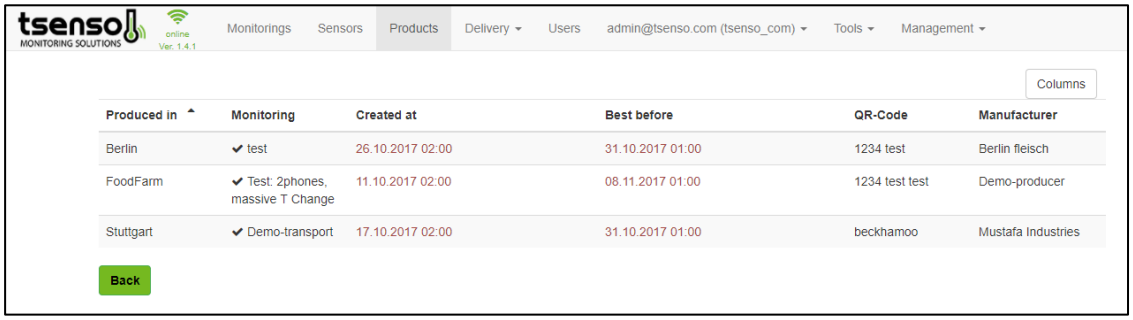

Figure 5: *Dashboard of products under management*

[1] https://en.wikipedia.org/wiki/Apache_Spark
[2] https://en.wikipedia.org/wiki/Scala_(programming_language)

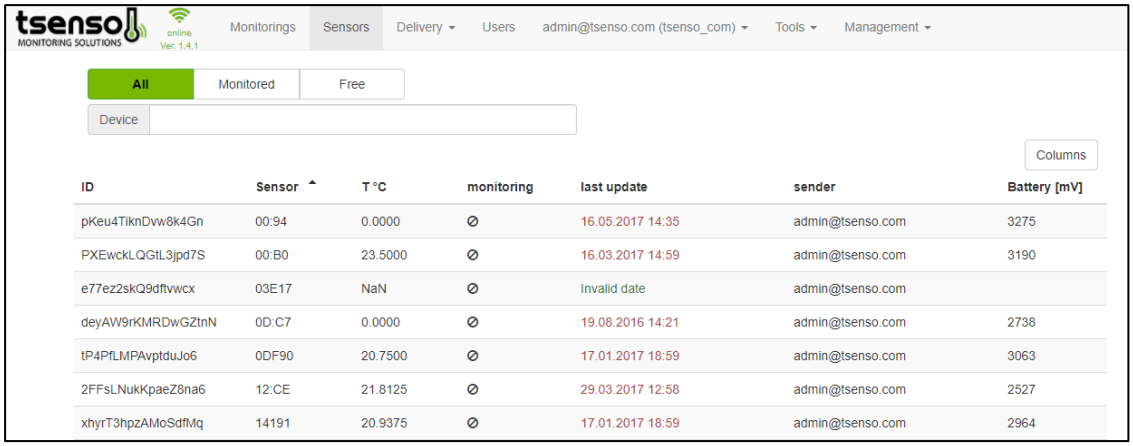

Figure 6: Dashboard of sensors under management

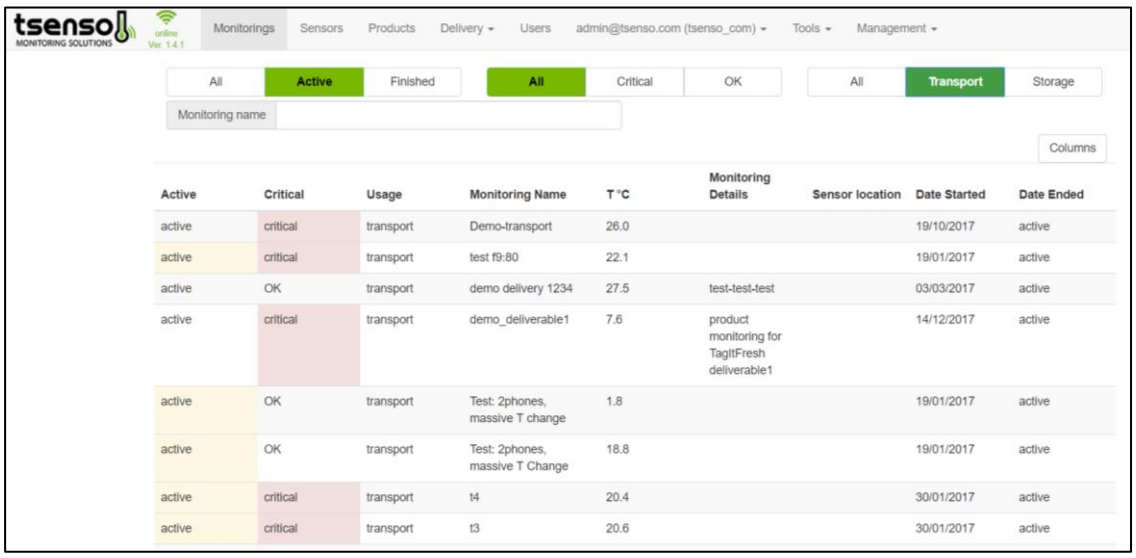

Figure 7: Dashboard of monitorings under management (filters: “active” and “Transport” set)

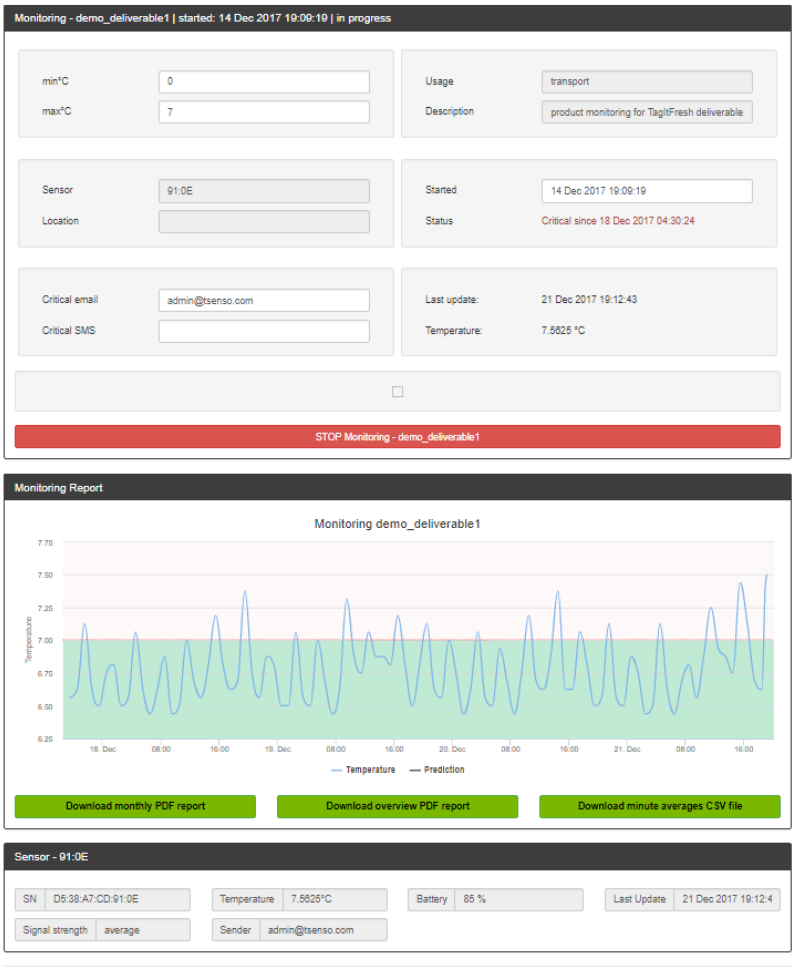

Figure 8: Detail view of a specific monitoring, including sensor details and data export

3.2.1 *Mobile application*

The mobile app is written in JavaScript using the METEOR framework,[3] a very fast and reliable way to build apps.

The app can be used by consumer as un-registered users for simple freshness queries and by professional, registered users for a complete supply chain management.

The FreshIndex scanning functionality is accessed by scanning the FreshTag label on the product via the “Scan product code” function

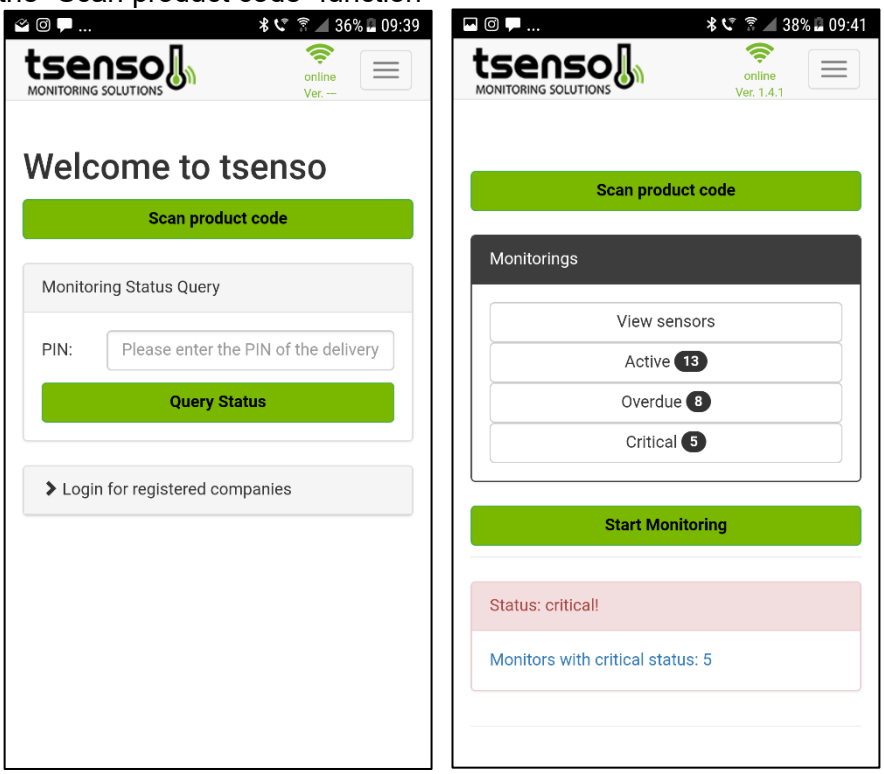

Figure 9: Access to the FreshTag scanner for consumers (left) and registered users (right)

[3] https://www.meteor.com/

Section 4 - Execution of the trial

At Univerexport departmental store, Novi Sad, a special TagItSmart counter has been set up with meat products provided by the manufacturer Bačka AD from Serbia. Meat packages arrived at departmental store on 05th May 2018 at 09:00.

First the store personnel manually managed the inventory and in parallel attached the Univerexport TagItSmart Tag on the products. A representative category manager and a sales representative from Univerexport organization was present all the time for the trial. They supervised the trail and provided information about the TagItSmart project to all consumers visiting the counter and to show them how the mobile application of TagItSmart works with the QR code.

At 09:45 meat packages arrived at the counter via the store personnel and were arranged on the counter. During the arrangement a representative from tsenso GmbH has attached the temperature data loggers with FreshIndex QR code to the 6 randomly selected Pork packets. Process of attaching the tsenso loggers and start monitoring the product goes in very simple few steps on tsenso mobile application as follows:

a. Stick temperature loggers to the product packet
b. Scan FreshIndex QR code
c. Fill in the details of product like name of manufacture, date of manufacture, expiry date, best before date
d. Start the tsenso temperature monitoring

Figure 10: Meat packets at Univerexport with TagItSmart tags attached

Figure 11: Meat packets at Univerexport store of TagItSmart counter

After following the above steps, the tsenso application directed the user to the FreshIndex screen. Initially user will see the screen with GIF circle representing the calculation of FreshIndex through the simulator on server side for about 0.5 to 0.8 seconds. At this point, the system is starting up and has only data entered by user available. As soon as the first temperature data arrives the FreshIndex is calculated. Definition of each number 1 – 5 for FreshIndex can be seen here in below image.

Figure 12: Definition of FreshIndex numbers

The definition and visualization of the FreshIndex is still an ongoing research work at tsenso in collaboration with the Hochschule Bonn-Rhein-Sieg. The complexity arises as the microbiological criticality of the food also depends on the planned processing of the food during the preparation of the meal, obviously sushi fish needs different freshness then deep-fried fish sticks.

When products were presented to consumers, a first significant decay in freshness was observed for FreshIndex level FI = 2.7 and lower. This level is typically present around the time when a product reaches the best before date printed on the label and constitutes the commercial end of shelf-life. These food products are still perfectly fine for consumption, especially when fully cooked. Only after reaching a FreshIndex level of below FI = 1, we advise consumers not to eat the product anymore for food safety reasons. This age of product marks the microbiological end of shelf-life.

In the final step step, the QR code of the TagItSmart labels is scanned via the tsenso app to link the two systems, tsenso and TagItSmart. In a first test, the Univerexport category manager scanned the TagItSmart QR code using the TagItSmart mobile application and the FreshIndex appeared almost immediately on the mobile screen.

The tsenso representative then continued with the registration of the remaining 5 products with tsenso sensor in the same manner. This manual registration of products can be automated in the future. Once all registered all products were kept in the counter for the next 4 hours. During this time the tsenso representative has explained the FreshIndex concept to the attending Univerexport personnel, so that it can be communicated correctly to the consumers in the local language. By the amount of people approaching to the counter and the extensive and detailed questions the consumer hat, we concluded that the concept of knowing the FreshIndex is of interested to the consumer.

At 14:30 the tsenso representative collected the products that had a tsenso sensors attached and packed it into the iso-thermal box then brought to Stuttgart, Germany for further lab testing, please see also section 4.2 Microbiological laboratory validation.

Figure 13: Images of activities at Univerexport Store with TagItSmart

4.1 User Experience

4.1.1 For Univerexport personnel

Using the tsenso mobile application by Univerexport personnel shall be extremely simple. App can be downloaded from Google Play app store following this link: https://play.google.com/store/apps/details?id=com.tsenso.monitoring

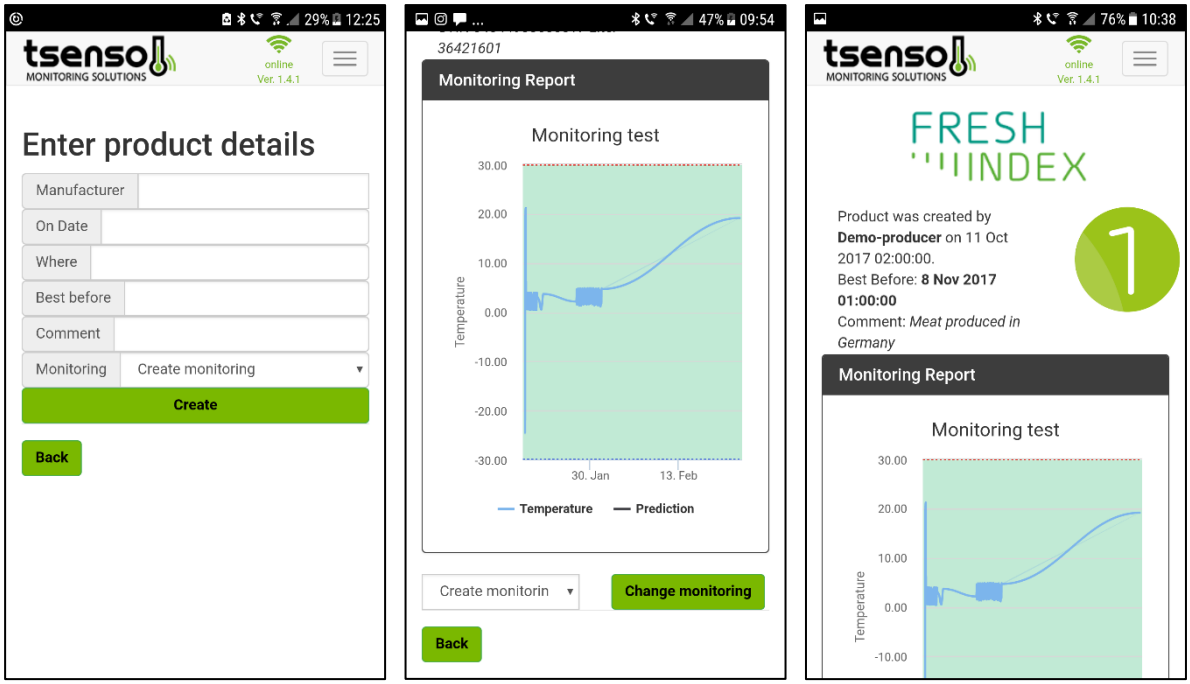

Figure 14: Detailed information on product data, accessible only to registered customers.

Once the app is on the smartphone then by scanning the FreshTag label, register users can:

- Enter new product (Figure 14, left)
- Assign a new temperature monitoring to a product, e.g. when it is moved from the truck to the warehouse or the attached sensor is exchanged (Figure 14, middle)
- Query the temperature history and the current freshness level (Figure 14, right)

Just by attaching the temperature logger to each product with few simple steps Univerexport can get the right freshness of the packed Pork meat on the tip of their smartphone. Critical temperature limit can be set and during the monitoring period if any criticality comes immediately the Univerexport responsible personnel will receive a notification on email on real-time to act.

4.1.2 For Consumers

With TagItSmart mobile application consumers can have in just one click the freshness of the product. It will be very interesting to the consumer to know about freshness of the product among other details of the product provided by the TagItSmart mobile application.

Today consumer is looking for the transparency of food ingredients and other provided by few market players globally. The main feature all these applications are lacking is to give info on the freshness of the food which is one of the most important health aspects. This crucial information is provided by tsenso integrated into the application of TagItSmart.

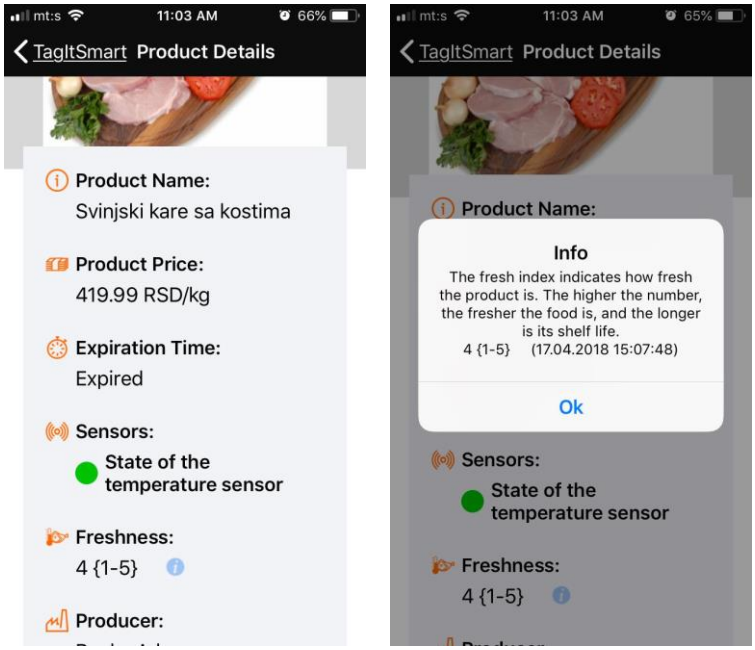

Figure 15: Picture of TagItSmart mobile application in action

4.2 Microbiological laboratory validation

In order to be able to compare the calculation results of the FreshTag module with the correct microbiological conditions, six meat products were taken from the TagItSmart shelf in the similar matter as a consumer would do and placed in a passively cool isothermal container at the point of sales. The products were transported by temperature-controlled air freight from Novi Sad, Serbia to Stuttgart, Germany.

In Stuttgart the products were handed over to the iPDP INSTITUT PIELDNER, Julius-Hölder-Str. 20, D-70597 Stuttgart, an independent, DAkkS accredited food safety laboratory. At iPDP the three samples were tested on the 07.05.2018, while two samples were stored for one more week at +4.0 °C and analyzed at iPDP on the 14.05.2018. The storage test was advised in order to check the long-time comparison of the FreshTag results also for dates past the expiry date specified on the product.

The results of the iPDP tests are listed in Table 1. One of the two products designated for the long-time storage showed a rupture of the modified atmosphere packaging. The time and cause of this rupture is not known precisely, but we assume that the damage occurred during the air transport. On advice of iPDP the sample was not included in the testing, as the results are not comparable.

Table 1: microbiological results of lab cross-check at iPDP INSTITUT PIELDNER

Report	Expiry date	Product details	Date of analysis	Weight	Total count	Advised limit	Leading microbes
206615	12.05.18	Raw pork meat (DGHM 2014)	07.05.18	535.4 g	2.8 10^3	5 10^5	pseudomonas
206616	10.05.18	Raw ground meat (DGHM 2014)	07.05.18	632.2g	2.9 10^4	5 10^5	pseudomonas, lactobacilli
206617	12.05.18	Raw pork meat (DGHM 2014)	07.05.18	600.0 g	4.0 10^3	5 10^5	pseudomonas
206618	10.05.18	Raw ground meat (DGHM 2014)	07.05.18	654.4 g	8.6 10^4	5 10^5	pseudomonas, lactobacilli
206767	12.05.18	Raw pork meat (DGHM 2014)	14.05.18	621,6 g	1,8 10^7	2 10^7	Lactobacilli, pseudomonas, Enterobacteri-aceae

The laboratory results and the calculation of bacterial growth of the FreshTag simulation module are plotted in Figure and show good accordance. The simulation overestimated the microbial activity and predicts a slightly faster spoilage than observed in the lab test. This is mainly due to the fact that the precise composition of the modified protection atmosphere was unknow and a default atmosphere was assumed. To improve the precision of the calculation details of the production and packaging process can be included into the algorithms. This promising work could be done as part of a future joint grant proposal.

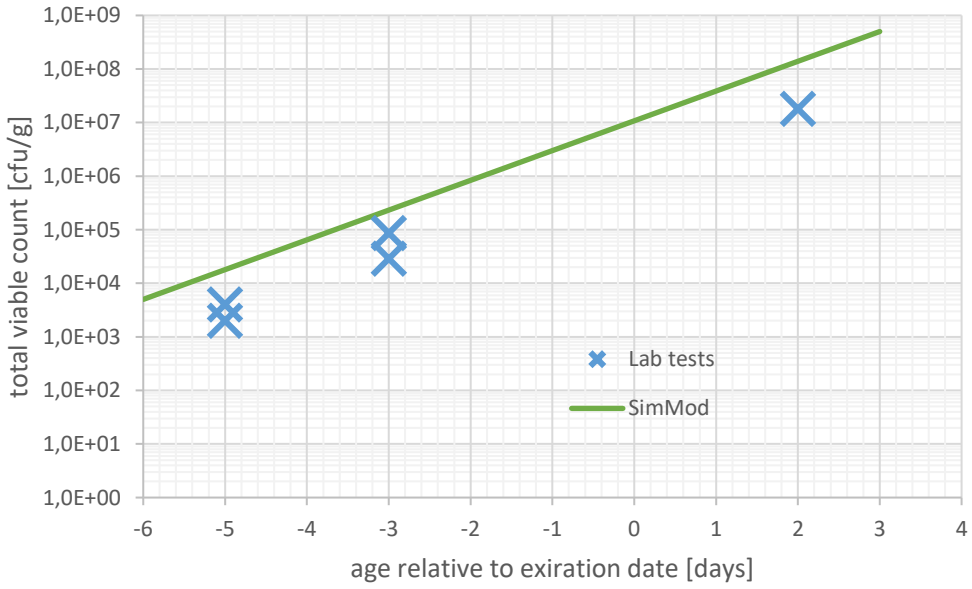

Figure 16: Comparison of calculation of the FreshTag simulation module and the lab test

Section 5 - Impact and Dissemination

5.1 Dissemination activities during the project

The following activities have been performed to increase the impact of the project:

- 09.09.2017 participating at the iFood Conference, Cologne, Germany
  20 business cards of potentially interested food representatives secured. Hottest contact: Mr. Gouloudies from Aldi Süd technology department
- 27.09.2019 Linked Open Data conference organized by GODAN - Global Open Data for Agriculture and Nutrition and Germany Ministry for nutrition and agriculture
- 15.11.2017 presentation of the project idea as plenary speaker at the 31 EFFOST conference in Sidges, Spain. For details on the program, please see:
  http://www.effostconference.com/resources/updateable/pdf/EFFO2017_Oral%20Programme%2001NOV17.pdf
  5 interesting contacts to European universities in the food production segment. One of the chairman, Prof. Buckenhüskes is also the president of Gesellschaft Deutscher Lebensmitteltechnologen (GDL e.V., "German society of food technologists") and the organizer of the 2018 Anuga FoodTech. After the presentation, he offered us to be also presenting at the Anuga FoodTech in March 2018.
- 27.11.2017 FIWARE TechSumit, Malaga, exhibition booth, tsenso joined the SmartAgriGroup of FIWARE
- 12.12.2017 Pitch at the EVC finals for the "start-up of the year" award,
  https://techtour.com/events/2017/12/event-evc-final.html
  Contact to 4 business angels and investors. Wiebke Langhans or the VR Equitypartner GmbH offered to introduce the FreshTag to the Westfeisch, one of the leading meat producers in Europe.
- 01.03.2018 Climate-KIC Berlin: Presentation of the preliminary project results to a German CO2 reduction competition. The project was ranked in the TOP10 but failed to win a price reward
- 23.03.2018 ANUGA FoodTech, Köln: Presentation of the preliminary project results to an international audience of food manufacturing, processing and quality assurance professionals. Good contacts to the Australian Meat and Livestock Association (MLA) and the Japanese Ashai Kasei Cooperation established.
- 08.05.2018 FIWARE Global Sumit, Porto, networking with SmartAgriGroup and International Industrial Data Space association.
- 24.04.2018, Participation at EU Startup Summit, Barcelona
- 29.04.2018 Meeting with the head of production and logistics of VION Convenience GmbH, one of Europe's leading producer of pork products
- 15.05.2018 METRO 2025, Warsaw: Demonstration of FreshIndex functionality as part of the METRO 2025 workshop on food innovation including monitoring for a meat transport from Warsaw to Germany.
- A first interactive Demo application can be downloaded at:
  https://play.google.com/store/apps/details?id=com.tsenso.monitoring&hl=de

Since November 2017 tsenso has started to promote the FreshIndex as a new alternative to the food expiry date in its social media channels:

MEDIA CHANNEL	PLANNED FREQUENCY	TOTAL # POSTS
TWITTER[4]	2/week	65
FACEBOOK (B2C)[5]	Weekly	16
FACEBOOK (B2B)[6]	Weekly	10
NEWSLETTER	6 / year	3
LINKEDIN[7]	Monthly	1

The use of Facebook was discontinued in March 2018 as Facebook has lost its credibility in the European market due to several data protection scandals. tsenso started using LinkedIn as a professional alternative to Facebook in April 2018.

5.2 Impact and Go-to-market strategy

5.2.1 Concept, Objectives, Set-up and Background

On order for the FreshTag simulation module to yield optimal results the design of the IT architecture needs to comply to the internal and external requirements. The development therefore starts off with an extensive requirement analysis. The result of this analysis was described in Deliverable 1.

Whereas WP1 established the structure and raw data exchange of the FreshTag module, WP2 fills it with meaningful functionality. The shelf-life prediction algorithms will be based on existing scientific work done by our Co-Founder Prof. Christian Fleck at Wageningen University.
In addition, to the algorithms, a supporting database including a model repository is investigated.

5.2.2 Lessons learned

To increase the product market fit, we have performed a strategic management workshop together with food officials on October 19th 2017, 11:00 – 13:00h at Metrostr. 1, Düsseldorf with the following participants:

- Sarah Blanchard, Global Quality Innovation, METRO AG
- Britta Gallus, head of Global Quality, METRO AG
- Nikolaos Bessas, head of supply chain quality, METRO AG
- Charlotte Rosendahl, head of supply chain management, METRO C & C Germany
- Alina Vutcariov, supply chain management, METRO C & C Germany
- Peter Kaleck, head of logistics, METRO Logistics GmbH
- Oliver Teschl, IT responsible of METRO Quality system, METRO Systems GmbH

[4] https://twitter.com/tsensocom?lang=de
[5] https://www.facebook.com/heutewasbesonderes (consumer targeted)
[6] https://www.facebook.com/tsenso.gmbh/ (B2B targeted)
[7] https://www.linkedin.com/company/tsenso/?originalSubdomain=de

Figure 7: Results of product target requirements

On request of METRO for reasons of confidentiality the detailed results of the workshop cannot be included here.

5.2.3 Commercial requirements

tsenso plans to continue the development of the FreshTag module in order to turn it into a reliable commercial product. As described in the requirement engineering section of deliverable FreshTag_D1 “Definition of IT architecture and Implementation” the clear pricing strategy has not been defined or validated. We identified the following commercial requirements:

Target of product pricing: *3% of cargo value*
Cost to value ratio: *1 : 20*

The value created by our solution, such as cost saving, fraud protection or increased revenues due to dynamic pricing must be more than 20 times cost of the solution. The maximum amortization period is not to exceed 24 months.

tsenso has executed a cost study for the operation and licensing of the solution. Based on this study, the commercial requirements are reachable.

5.2.1 Next steps

The development of the FreshTag module to a mature commercial product is the key target for tsenso in 2018 and 2019. tsenso has acquired a first implementation project with METRO cash & carry Germany for the monitoring of the German pork supply chain.

In parallel, tsenso is looking for a second pilot implementation outside Germany.

Section 6 - Conclusions

The FreshTag module has been developed successfully as part of the TagItSmart Open Call. The module offers the functionality of gapless temperature monitoring from the production of food to the presentation shelf inside the retail store. The solution offers food producers, logistics and food retailers the basic capabilities needed for professional use, such as user and permission management and an easy to understand dashboard. To reduce handing errors and cost connected with manual work, the sensors do not have any on/off functionality but the system if automatically managed by the cloud.

As Described in deliverable FreshTag_D2 “Microbiological Shelf-life prediction” an algorithm for assessing the effect of the exposed storage temperature on the growth of microbiologic spoilage has been implemented and validated by laboratory measurements. The system was finally tested as part of the TagItSmart field test in collaboration with DunavNET and Univerexport. During the trail the FreshTag system functioned flawlessly. The temperature monitoring was extended from the point of sale at Univerexport, Novi Sad to include the transport of six samples via airfreight to Germany, where they samples were analyzed regarding their microbiological conditions. The lab results matched well with the prediction of the FreshTag module. The positive results may lay the foundation for future, extended projects for longer supply chains or to include different kinds of food products.