Executive Summary:
Food processing activities produce large amounts of by-products and wastes in Europe which are only partially valorised. One third of the food produced in the world for human consumption every year, approximately 1.3 billion tons, get lost or wasted. NOSHAN investigated the process and technologies needed to use food waste for feed production at low cost, low energy consumption and with maximal valorisation of starting wastes materials. Nutritional value and functionality according to animal needs as well as safety and quality issues were investigated and addressed as main leading factors for the feed production using food derived wastes and by-products. Two different groups of activities were investigated: i) replacement of bulk feed raw materials using wastes/by-products that can help decrease part of the amounts of food waste generated in Europe and ii) obtaining feed additives from food waste in order to better maximise the use of waste.

NOSHAN project has created a broad portfolio of relevant food wastes/by-products in Europe for feed production according to multiple criteria. From this portfolio several wastes were selected and characterized down to a molecular level. This data base is public in order to be used for the scientific community for further studies and projects. The cascade approach strategy allowed the identification of several waste streams with high potentiality to be exploited. But only part of them have been scaled up and validated. In this way NOSHAN project identified interesting candidates for future research.

This full characterization allowed the identification of the most interesting food waste streams to be processed and the best valorization path per each stream for bulk feed ingredients or additives. A variety of high-advanced technologies for conditioning, stabilising by physico-chemical and biological strategies, extracting biofunctional feed additives with high-added value and suitable raw materials for bulk feed were evaluated. A range of compounds and feed production were successfully developed, tested and integrated to produce safe and functional feed. Additionally, relevant technologies have been developed during the project demonstrating the application of these innovative technologies for the production of feed ingredients by the use of by-products.

All these results were validated in in vitro and in vivo tests with animal trials, piglets and broilers. Animal trials included testing bulk feed ingredients and functional additives. Animal trials demonstrated that functional ingredients and also bulk ingredients from food waste and by-products can replace part of the current raw materials for monogastrics maintaining the health and welfare of the animals. Moreover, it was demonstrated that feed formulations with NOSHAN ingredients have food nutritional values and are safe.

A whole value chain from starting raw materials to exploitable products and technologies were covered and monitored with a Life Cycle Analysis. LCA demonstrated that the replacement of feed ingredients with ingredients derived from food waste and by-products had a clear positive impact on the sustainability of the feed production chain.

The results achieved demonstrate the feasibility of food waste valorisation for feed production and their viability as substitutes
for the currently used feed raw material.

Project Context and Objectives:

NOSHAN Concept

The main focus of NOSHAN was to investigate the process and technologies needed to use food waste for feed production at low cost, low energy consumption and with maximal valorisation of starting wastes materials. Nutritional value and functionality according to animal needs as well as safety and quality issues were investigated and addressed as main leading factors for the feed production using food derived products (fruit/vegetable/plant and dairy). According to this not only wastes are characterized for their nutritional potential, but suitable technologies to stabilize them and convert them into suitable raw materials for bulk feed were researched. Obtaining functional feed ingredients (additives) from these wastes was also targeted as it constitutes an important factor determining final feed cost and functionality in animals. Two different groups of activities were thus addressed: on one side, replacement of bulk feed ingredients (constituting up to 90-95% of feed weight) were studied from the starting waste materials. These bulk materials could cope with part of the huge amounts of food waste generated in Europe. On the other side, the valorisation of active ingredients as well as the upgrade of waste into more valuable feed additives was studied. The later constitute approximately the half of the feed cost. Therefore targeting technologies from cost efficient materials such as food waste could decrease feed costs.

The main result of NOSHAN project was the creation of a broad portfolio of valorisable wastes for feed production. In this sense, a selection of wastes according to their potential nutritional properties, quantities produced, seasonality, possibility of stabilisation, safety and regulatory issues, cost and logistics was performed during the first phase of the project. In addition, a number of wastes were studied in NOSHAN since the beginning of the project due to their great importance for European Agriculture production or to their nutritional composition. In order to improve nutritional content of feed and be able to fulfil animal needs, waste were treated alone or mixed with other waste looking for complementation and synergistic effects. The characterisation at molecular level of the different waste streams allows providing the best technology for the best raw material to obtain the desired nutritional/functional properties.

During NOSHAN a variety of high-advanced technologies for conditioning, stabilising by physico-chemical and biological strategies, extracting high-added value compounds and feed production were tested, developed and integrated in an innovative low-cost and low energy tailor made procedure for valorising food waste for production of safety and compound functional feed. All these results validated in in vitro and in vivo tests to the final animal derived products intended for human consumption. Therefore a whole value chain from starting raw materials to exploitable products and technologies was covered and monitored with a LCA with a further validation using the novel European Technology Validation platform.

Context

Food waste is a potential source of big quantities of nutrients. Based on its composition, it can be an important feed supply not only for feed bulk ingredients but also for special functional foods and additives. Plant and dairy waste and by-products could be an excellent source of, for example: i) protein hydrolysates; ii) functional protein hydrolysates (enriched in active peptides for promoting gut health, enhance immune response); iii) fibre with prebiotic properties which can improve the health of the gut; and iv) antioxidants, vitamins or polyphenols which can improve the oxidative status and enhance animal performance.

Despite the obvious potential, the utilization of feed from waste in diet formulation until now has been negligible, due to several nutritional and technical constraints. Taking the aforementioned background into account, NOSHAN investigates new tailored valorisation paths for fruit, vegetable, root and tubers, cereals as well as dairy wastes by developing new technological / biotechnological and downstream processing tools for the production of functional and safe feed.

NOSHAN considers wastes generated in all stages of the food chain, from agriculture to consumption. Therefore a platform of waste providers supplied these wastes for the research activities and scale up. In this sense, a selection of wastes according
to their potential nutritional properties, quantities produced, seasonality, possibility of stabilisation, safety and regulatory issues, cost and logistics were performed during the first phase of the project. NOSHAN aimed to take maximum number of data into account to create a prioritized list of target wastes. The composition, presence of potential pathogens/contaminants and the nutritional value of selected wastes were thoroughly analysed. The characterisation at molecular level of the different waste streams allowed providing the best technology for the best raw material to obtain the desired nutritional/functional properties.

As NOSHAN follows two approaches, development of bulk feed and active ingredients, using this double fold strategy, NOSHAN finds a solution to cope with part of the huge amount of organic food derived waste for bulk feed production but at the same time derives part of these streams to higher upgrade valorisations via feed additives production. In this sense NOSHAN addressed not only a solution for bulk feed in terms of quantity but also a solution to decrease feed costs by studying additive production strategies from inexpensive organic wastes.

The seasonality of wastes imposes a determined period for feed production and high production rates or waste spoilage and degradation can occur. NOSHAN evaluated several physic-chemical and biotechnological stabilization approaches to overcome this drawback. Suitable stabilization technologies were identified for target wastes or mixtures thereof thus allowing the use of wastes as more durable raw materials and enhancing the possibility of waste mixtures. Among physico-chemical stabilization technologies, drying plays an important role but it is not the only one. Previous dewatering strategies based on electro-agglomeration for dairy wastes and mechanical pressing for fruit/vegetable/plant based waste were evaluated. The main goal of these pre-treatment technologies was to extract the maximum water content at minimum energy demand. When waste presented acceptable water content, a 2-in-1 acid concept was used: traditional acid addition for stabilization but with a surplus in nutritional value for animals. Those wastes that had high water contents and activities were also treated with drying technologies. Two innovative technologies were used and compared to more traditional approaches: infrared drying and refractance window drying. Both technologies bring substantial energy savings and significant reduction in production running costs.

Apart from physic-chemical technologies, other biotechnological approaches were studied. Their impact on raw wastes can affect especially in the improvement of their nutritional value in terms of protein and also in product safety related to the pH decrease that some fermentation processes can produce. Technologies such as ensiling or in situ solid state fermentation were investigated. The use of certain microbial strains as process inoculums also added extra plus in terms of functionality of the raw bulk materials thus adding a plus in waste valorisation for feed.

For feed additives from food wastes several potentially marketable products were studied based on consortium partners’ background. Specific animal target needs were addressed: antimicrobial, anti-inflammatory, antioxidant, agglutination compounds as well as molecules impacting on positive feed taste. Bioactives and functional ingredients obtained were deep characterized down to a molecular level as well as an in vitro validation of their functionality with an animal digestive model that is able to simulate the digestion process. It was very important to understand if functional molecules were able to surpass this process or if they needed to be protected or target delivered used. The proposed technologies had the clear objective of reducing the overall cost, energy and chemical demand of the production process.

Compounded technologies were analysed and their impact to final nutritional value and feed safety evaluated. The utilisation of planetary roller extrusion, widely utilised in other fields but novel in feed production, was specially monitored. This technology is expected to bring reduction in energy demands, increase in feed safety and durability and suitable throughputs when working with stabilised wastes and mixtures thereof as co-streams. Additionally, feed production technologies were evaluated for their impact on feed additives degradation through processing. Coating and microencapsulation technologies were used in extrusion and planetary roller extrusion to protect bioactives.

Selected technologies were applied according to compositional and nutritional characterization as well as target animal feed
requirements. Pigs and poultry were target groups because their consumption represents approximately three quarters of meat consumption in Europe and they also play an important role in world wide breeding species. NOSHAN efforts were directed to these species but the developed strategies and technologies could then also be transferred to cattle, sheep, goats and other animal bred species. Weaning piglets and poultry were selected. In these trials target animals were fed with a diet based on produced feed. Animal welfare as well as their needed sources of fresh water and breeding conditions were considered and respected. During animal trials not only the growth performance and animal health were considered but also the quality of the resulting meat derived products was evaluated. Meat and animal derived products safety for human consumption was also monitored.

In summary, NOSHAN considered the whole value chain from starting raw materials to final animal derived products for human consumption. Process sustainability was evaluated through the realization of a complete LCA. Energy consumption, water usage and chemicals utilization were key parameters evaluated in each technology analysis. At the end of the project the sustainability improvements of the process and the evaluated technologies were also assessed via the European Technology Validation Platform. The main objectives of these activities were to obtain quantitative data that can determine the sustainability of the process for further commercialization or as a reference for policy makers.

General and specific objectives

NOSHAN main scientific and technical objective was to enable the use of food waste for functional and safe feed production at low cost, low energy consumption and with maximal valorisation of starting materials. It included both the use of food wastes (fruit/vegetable/plant and dairy) for bulk feed production and for obtaining functional ingredients and bioactives.

The specific objectives of the project were:

1. To create a broad portfolio of fruit, vegetable, root and tubers, cereals and dairy wastes products suitable for their valorisation to produce safe and functional compound feed which fulfil animal needs. Therefore an exhaustive survey of quantity of wastes produced, seasonality, potential nutritional properties and regulatory issues needs to be performed as well as a full characterisation of representative samples of these wastes. The portfolio contains the new data and also a compendium of collected data from other published studies and publications.

2. To define appropriate technologies to apply to each waste among a range of low-cost and effective physico-chemical and biotechnological procedures in order to: i) condition and stabilise them to decrease the impact of their seasonality (improved preservation); ii) improve their nutritional values in certain processes; and iii) ensure the safety of the raw material in terms of microbial safety. This was of special relevance in dairy/fruit and vegetable derived wastes since their water content is high and can be readily contaminated if they are not used in short time after production. NOSHAN brings a progress in this aspect.

3. To produce and extract specific feed additives (functional fibres, protein hydrolysates enriched in active peptides and functional molecules with antioxidant, antimicrobial, anti-agglutination and anti-inflammatory properties) from food wastes utilizing technologies that allow to reduce functional ingredients production cost (low-cost starting materials and lower energy demand). The new ingredients were characterised at molecular level and their functionality and bioavailability was validated by in vitro models.

4. To combine synergistic composition properties of each stabilized wastes or mixtures of it to produce a starting material that can fulfil animal needs. For this objective, the full characterization of wastes after stabilization brings a valuable source of information.

5. To produce safe and functional compound feeds from stabilized wastes and functional feed additives developed in NOSHAN which fulfil animal needs at low cost, energy demand and acceptable production rates for market needs. Microbial and contaminant safety is specially monitored and related to the positive impact of evaluated feed production technologies.

6. To demonstrate the feasibility of the procedures at pre-industrial level by scaling-up the most efficient technologies.

7. To validate the efficacy of the functional compounds on the performance, product quality, health and welfare of weaning pigs and poultry in animal trials. These animals and growth stages have been selected as representative of the most relevant meat sources in Europe and critical breeding stages.
8. To realize an environmental evaluation, using Life Cycle Assessment (LCA) and Environmental Technology Verification (ETV) tools, of feed production from food waste following NOSHAN approach that enables a quantitative validation of the sustainability of the proposed processes and products through the whole value chain.

9. To evaluate the technical and economic viability of NOSHAN processes and products by risk evaluation and technical and market barrier identification during the project execution that can confirm the viability of the proposed strategies and products.

10. To properly disseminate project activities and results among a wide representation of stakeholders and research community partners that can be potential beneficiaries of the project results.

Project Results:

WP2: Food waste characterization and final selection

The main objective of the WP2 was to create a portfolio of characterized plant and dairy waste streams which could be valorized for producing safe and functional feed fulfilling animal needs. The WP2 was central in the project, since it has to provide data to take educated decisions on which food waste streams were to be used for developing technologies both for bulk feed production (WP3) and for feed additives production (WP4). In order to reach this target, a three-step approach was devised: 1) Selecting the food waste streams to be analysed according to the data present in literature and databases; 2) Fully characterizing, down to the molecular level, the food waste materials selected, both in desirable and undesirable components; 3) Defining, according to the compositional data, the suitability of the different raw materials to further processing into bulk feed or feed additives.

Thus, as a first step, a portfolio of all the potential waste streams was created. Databases such as FAOSTAT, PSD Database (USDA), COMEXT and Danish Food Composition Databank were taken as main sources of data. When the required data were not available in those databases, other sources such as other international databases, reports, scientific articles and specialized web pages were consulted. More than 200 references were used in Portfolio, mostly containing 2009 year data. The portfolio took into account five main issues which were considered important to assess the potential of a food waste streams: 1) quantification of the most important fruit, vegetable, cereals roots and tubers produced in European Union, including raw and processed materials/food and importation and exportation of raw materials and processed food; 2) quantification of wastes produced at harvesting of raw materials, storage, transportation, processing, distribution and final consumption stages; 3) seasonality of waste production from harvesting of raw materials (cereals, roots and tubers, oilseeds and pulses, fruit and vegetables, and other); 4) physico-chemical and nutritional characteristics of wastes (when available); 5) potential contaminants, problems and current uses of wastes. At the end, a scoring system for selecting the food waste to be analysed in the project was devised, taking into account, in a very simple form, all the parameters reported above.

Then, in the second step, about 40 waste streams coming from all part of Europe were selected for the analysis. The following waste streams were considered: sauerkrauts, apple pomace, brewing cake, parsley, hard cheese, soft cheese, mixed cheese, fresh cabbage, sour cabbage, apple cake, fresh pumpkin, sauerkrauts, barley rests, beer yeast, pumpkin kernel cake, malted barley germs, pea hulls, sugar beet flakes, yoghurt, milk whey, malted barley germs, berry waste, sabal (Serona repens), seabuckthorn seed, seabuckthorn pulp spent grain, hop, onion hulls, fresh onion slices, rapeseed press cake, potato skins, potato selected, jerusalem artichoke (topinambur) press cake, olive pomace, orange peels, grape pomace, tomato skins, belgian endive root, belgian endive leaves, leek leaves, whole apples, whole pears, mushrooms. Moreover, also household waste only including vegetables and dairy was collected in Flanders, Spain and Italy and it was considered for analyses.

The following analyses were done on the selected food waste streams in order to evaluate their nutritional content: Water content (NS, LEITAT, IGV), Volatile content (LEITAT), Ash content (LEITAT, NS), Total mineral matter (IGV), Hydrochloric acid insoluble minerals (IGV), Fixed Carbon (LEITAT), High and Low heating value (LEITAT), Crude Fat (IGV, NS), Fatty acid distribution (IGV), Crude fat after hydrolysis (NS), Sugars (NS, IGV), Elemental analysis C%, H%, S% (LEITAT), Nitrogen (LEITAT, NS, IGV), Soluble nitrogen (NS), Total amino acids (UNIPR), Free amino acids (UNIPR), Amino acid Racemization (UNIPR), Peptide Profile (UNIPR), Protein profile (UNIPR), Microelements (LEITAT, NS). Moreover, the following analyses were also
performed in order to evaluate the functional content: Vitamin A (NS), Vitamin E (NS), crude fiber analysis (NS), Pectin amount (UNIPR), Uronic acid content in pectins (UNIPR), Monosaccharide composition in pectins (UNIPR), Degree of methylation in pectins (UNIPR), Degree of acetylation in pectins (UNIPR), Insoluble Dietary Fibre (IGV), Soluble Dietary Fibre (IGV), Inuline (IGV), Oligofructose (IGV), Beta-glucans (IGV), Phenolic compounds (IGV), Essential oils (IGV).

According to the analyses reported above, some food waste streams turned out to be very promising for further elaboration in the project, since they contain good amount of nutritional or functional compounds. In particular:
- Cheese: rich in high quality proteins, fats, vitamin A, selenium.
- Pumpkin kernel cake: rich in proteins, zinc, copper and manganese.
- Barley: rich in proteins, beta glucans, vitamin E, zinc, copper, manganese, selenium
- Brewing cake: rich in proteins, copper, zinc, selenium, fat, vitamin E.
- Yoghurt, whey: rich in lactose.
- Mushrooms: rich in selenium, zinc and copper, beta glucans, high quality proteins.
- Olive pomace, sugar beet flakes, berry waste, fresh pumpkins, onion slices: rich in pectins.

Also household waste bulk analyses (proteins, water, fat, sugars and fibers) were performed, on samples collected in three different countries, outlining an amazing stability of the composition among the different countries. If this stability should be proven constant on more samples, this would make household waste a very promising starting material to produce feed. In order to also assess the content of undesirable compounds in the selected waste streams, mycotoxins, biogenic amines, agrochemicals, heavy metals and microorganism contamination were also assessed in the above reported samples. Mycotoxin analysis on waste samples outlined the general absence of ochratoxin A, which might be related to mould contamination after the transformation of food in waste. Occasional contamination problems were found for barley (fumonisins and trichothecenes) and grape pomace and apple (patulin), but these mycotoxins were there only because they were already present in the starting food commodity, not as a consequence of the transformation in a waste. Biogenic amines were a problem only in the sour cabbage samples, which were highly fermented by bacteria producing these amines. Pesticides, fungicides and herbicides were often present, but always in amount lower than the legal limits. Heavy metal contamination was not found to be present at levels which might be cause of concerns. Finally, microorganism contamination by bacteria and fungi was generally found low and never exceeding legal limits. All the above data indicate that the food waste streams analysed are in general safe form the chemical and microbial point of view, even if for some compounds (mycotoxins and agrochemicals) a close monitoring on the used raw material is always advisable.

Finally, using all the data collected, all the waste streams were scored according to the following parameters: nutritional, biofunctional, economical and risk assessment. These parameters were combined according to the intended final use, bulk feed or additives. Risk assessment was used in both cases, and so the economical score, but with a different weight, very important in case of bulk feed, where we do expect a little added value, then marginal costs are important to be low, and not so important for additives, where we do expect a big added value, so marginal costs impact less. Based on these scores, and also considering the technofunctional properties of the different food waste streams, which might require or prevent a given technology, the following food wastes were finally selected for testing the technologies for bulk feed production: cheese residues, pumpkin kernel cake, malted barley germs, brewing cake, yogurt, milk whey, fresh pumpkin, rapeseed press cake. On the other side, the following food wastes were finally selected for testing the technologies for additives production, according to the content of the specific additive desired (pectins, peptides or other bioactives): for pectin-rich wastes (intended for pectic oligosaccharide production), olive pomace, berry waste, fresh pumpkins, sugar beet flakes, fresh pumpkin and onion hulls; for protein-rich wastes (intended for peptide production) cheese residues, pumpkin kernel cake, malted barley germs, brewing cake, rapeseed presscake; for bioactive-rich compounds: cheese residues, pumpkin kernel cake, malted barley germs, brewing cake, sauerkrauts, olive pomace, sugar beet flakes, berry waste and fresh pumpkin.

The results of these WP allowed to actually identify, based on hard data, food waste streams with potential to be transformed...
in high quality feed or to be used to extract potential bioactive compounds to be applied as additives. Moreover, in this WP for the first time it has been created a database containing hundreds of analyses for 42 food waste streams, useful for all the scientific community as future reference dataset.

WP3: Waste conditioning and stabilization

The main objective of WP3 was to analyze the conditioning processes from starting materials chosen in WP2. These conditioning pretreatments have been addressed to: i) ease the utilization of the raw wastes; ii) improve their nutritional values in certain processes; iii) ensure the safety of the raw material in terms of microbial safety; iv) decrease the impact of their seasonality by enabling storage of the stabilized food for a smoother production rate; and v) ensure the adequacy of the stabilized waste as a raw material for feed production.

In this sense, the first step to fulfil the objectives of this WP was to evaluate different fraction, dehulling and mixing strategies in order to obtain the most favourable compositional, nutritional and functional potentialities for the final feed products (these activities were carried out by IGV). The main results of these trials showed the strategy to follow for the mixing of wastes in a double fold approach: on one hand, nutritional value of mixed wastes is improved when compared to the streams alone and, on the other hand, technological mixing is also applied to minimize the energy expenditure during stabilization strategies, mainly drying. As an example, fractions were obtained from some materials, such as rapeseed presscake (protein-rich kernels and fiber-rich hull fraction); barley germs (e.g. hulls, grains, fine straw); and barley spent grains (e.g. gross straw, grains, fine straw).

After analyze the different techniques for a proper fraction and mixing, the second step was to assess several physicochemical and biotechnological strategies for stabilizing the selected materials. Regarding to the physicochemical strategies, three groups of technologies i) drying, ii) acid conservation and iii) solid content separation were studied. The drying technologies and the conservation with the organic acids, mainly sorbic acid and medium chain fatty acid (MCFA) concepts, proved to be suited for stabilization of the selected substrates, while solid content separation show good results as a pretreatment.

All drying technologies tested [3-belt; infra-red (by IGV); and refractance window (RWD) (by ILVO)] were able to sufficiently lower the water activity (below 0.65) and keep enough moisture in the product for an optimal digestion (between 5-10% MC). However, the drying techniques tested were not always suited for every type of food waste (e.g. mixture of lactic materials). In order to stabilize bigger amounts, the 3-belt-dryer was most effective, because the process runs continuously (however, it is not suitable for all products, such as cheese). RWD technology presented a faster stabilization than cabinet drying (air drying), as well as shown less energy consumption compared to similar technologies.

On the other hand, the organic acids, mainly sorbic acid and MCFA based concepts, were appropriate to conserve and improved the nutritional value of the selected substrates. These experiments were performed by NS. The beneficial lactic acid bacteria (LAB) were able to grow in these brines, but the pathogens did not under these conditions.

In the case of the solid content separation, it was not possible to stabilize the selected materials with the techniques tested [electric field separation (by AQON) and mechanical pressing (by PROVALOR)], however, these techniques have more potential as a pre-treatment process prior to the stabilization processes, drying or conservation with organic acid. As a pre-treatment process they efficiently divide a waste stream into a solid fraction and aqueous fraction. However, the use of these technologies as pre-treatment of food waste prior to further processing into feed increase the effectiveness of food waste valorization in this project.

Regarding to the stabilization via biotechnological strategies, the aim was to test and choose the best strategy of different kinds of wastes and mixtures thereof. Two approximations were tested: i) natural ensiling: fermentation by bacteria naturally
present in the substrate; and ii) inoculated ensiling: fermentation by bacteria inoculated to the substrate. These trials were performed by VERTECH and UCKERKAAS. The experiments were tested on two standalone substrates and two mixtures. In all the cases, the control of the endogenous microflora by a LAB inoculation was highly recommended, to avoid ethanol production and speed up the decrease of pH by lactic acid production. In the same line, results shown that to control yeast growth and prevent ethanol production, the utilization of facultative heterofermentative lactic acid bacteria, producing, apart from lactic and acetic acid, propionic acid, is recommended. Propionic acid would be interesting because of its inhibitory activity on yeasts and fungi, and its ability to improve stability of the product during its final utilization. Moreover, the utilization of endogenous LAB strains, selected after natural ensiling of the substrates and therefore perfectly adapted to their nature is highly recommended. In addition, the ensiling process allows anyway the growth of lactic acid bacteria and therefore, in appropriate conditions, a protein content enrichment of the product.

Upon the stabilization of the materials by using the both physicochemical and biotechnological strategies, the products were characterized (LEITAT, UNIPR, VERTECH, IGV, NS and ILVO). The mycotoxin analyses allowed to conclude the only mycotoxins present in high amount were those deriving by the original food material (fumonisins and tricothecens in cereals, for example). This indicates that, as far as mycotoxin contamination is concerned, the critical points to be checked were the raw materials at the beginning of the production chains. From the pesticide analysis it was clear also that in the majority of the wastes, the values are below the detection limit. Respecting to the results of microbiological analysis performed, showed that all samples are free of Escherichia coli, Aspergillus spp., Clostridium perfringens, Listeria monocytogenes and Salmonella ssp. This is a clear indication that the stabilization procedures are well thought-out and are successful in avoiding E. coli contamination of samples mainly in the light of the fact that several raw material (original) samples had shown the presence of E. coli.

On the other hand, results obtained from the composition of the nitrogen and pectin fractions shown that dried yoghurt has the highest potential by its high fat and sugar content. In addition, it has good preservation characteristics by its low pH and dry nature. Due to its low free fatty acid and peroxide number, it tends not to deteriorate feedstuffs. However, lactose content is low. Excellent protein nutritional value and amino acid profiles were shown by rapeseed presscake mixtures with cheese, yoghurt and whey, as well as by barley spent grains mixed with yoghurt and cheese, and also pure yoghurt has shown potential for integration in upcoming feed formulations, nevertheless mushroom appear to be a perfect ‘natural cysteine additive’. All other wastes have shown low to very low content in essential aminoacids.

Further on, best cases for avoiding rancidity were also obtained by drying techniques. These results were evident in dried fresh pumpkin. Mushrooms and ‘Malted barley germs + yoghurt’ can also be safely used, but are not rich in nutrients. Fermentation products, such as fresh pumpkin and leek leaves tend to some potential, however, they have a low nutritional value.

Finally, the aqueous effluents after the stabilization techniques were also characterized (LEITAT). Effluents have been analyzed in terms of typical wastewater treatment parameters. Results revealed that all effluents contain high loads of organic matter, nutrients and some metals. They are not dangerous and do not pose an environmental risk. Wastewater treatment is possible either for discharge or reutilization purposes. However, the amount of nitrogen/protein was too low to consider this stream for further valorization.

Summarizing, the results of WP3 allowed to identify the best strategies to conditioning and stabilizing the starting materials proposed in WP2. In the same line, methods for improving the nutritional values were tested in this WP. The stabilized materials were analysed in order to identify their potential for feeding, showing promising results. Finally, the results obtained in WP3 were fundamental as starting point for the scale-up activities developed in WP6.

WP4: Waste conversion into feed ingredients
The main objective of the WP4 was to produce specific feed additives from the selected food waste coming from WP2. In order to reach this objective, it was defined different tasks: i) Development of a selective process for obtaining biofunctional fibers (VITO), ii) Development of a selective process for obtaining biofunctional protein hydrolysates enriched in active peptides (LEITAT), iii) Development of a process for obtaining biofunctional molecules with antioxidant, antimicrobial, agglutination and anti-inflammatory properties (NS), iv) Characterization at molecular level of the feed additives (UNIPR) and v) Functional demonstration of the feed additives in inv vitro models (NS and LEITAT).

In WP4 different functional ingredients have been obtained. Regarding to fibre, functional pectin polysaccharides (POS) have been obtained from sugar beet pulp, onion hull waste and berry pomace with prebiotic activity. Regarding to protein, functional protein hydrolysates from rapeseed presscake showing antioxidant and anti-inflammatory properties have been obtained as well as functional protein hydrolysates from mushroom and leek with antimicrobial peptides Functional direct extracts have been obtained from deffated cheese residue (proteins), olive pomace (polyphenols). Molecular characterisation of fibers, protein hydrolysates and direct extracts have been obtained and the bioavailability has been studied. Moreover, valorisation of residual biomass generated during the extraction of actives was evaluated in order to propose possible valorisation routes.

Sugar beet pulp (SBP), olive pomace (OP), berry pomace (BP), pressed pumpkin cake (PP) and onion hull waste (OH) were chemically and/or enzymatically processed to produce pectic oligosaccharides (POS) which were tested for their prebiotic properties to be used as feed additives. The full process consist of two parts, being (1) a pretreatment to either make the raw material more accessible, either liberate the pectic polysaccharides and (2) an hydrolysis in a membrane type of reactor to produce tailor made oligosaccharides.

As a basis, two type of extraction procedures were investigated, one the more conventional acid assisted (nitric acid-NAE) and the other, enzymatically assisted (EAE). Results showed different performance depending on the waste.

- nitric acid assisted extraction of 4h was selected for sugar beet pulp (SBP),
- 0.5 h treatment with 2.0 % (w/v) sodium hexametaphosphate for onion hull waste (OH)
- nitric acid extraction - NAE treatment of 2h was selected for berry pomance (BP)
- enzymatic assisted extraction - EAE treatment of 12h for pressed pumpkin cake (PP)

The BP and PP gave however significantly lower yields for the pectin polysaccharides as compared to SBP and OH, and were therefore not considered for the hydrolysis experiments. Because of the easiness of operation and lower cost, it was selected the nitric acid based extraction.

By performing the hydrolysis in a membrane enzyme reactor (MER), the POS are removed from the reactor before being further hydrolysed, potentially providing an improved tailoring and efficiency. In order to obtain tailored hydrolysates, the hydrolysis was also performed in a membrane enzymatic reactor (MER), and several process options were investigated to optimize the process. POS fraction could be generated, both from SBP as well as OH by performing the hydrolysis by dosing 10% (v/v) of a diluted solution of viscozyme (0.6 FPU/ml). The best results were achieved with approximately 31% of monosaccharides and 69% of POS. In addition, by post-filtration, several fractions of POS could be generated.

POS production with membrane enzyme reactor with sugar beet pulp has shown prebiotic activity.

- no POS stimulated Escherichia coli growth
- the Lactobacilli stimulations are very much strain dependent: no “good-for-all” preparation seems possible
- the Lactobacilli stimulation is also batch dependent: not all the batch work well even on the same strain. Some batches even inhibit lactobacilli growth
- mostly stimulating seems to be the ones having high DP arabinans and rhamnogalacturonans

A clear indication on the preparations richest in POS, and on their composition in oligomeric sugars, both in terms of degree of polymerization and on the monomeric units, was obtained. This will allow linking the molecular composition to the technology used to obtain the POS preparation, from one side, and to the prebiotic activity shown by the different preparations, from the other side.
For the production of functional peptides different technologies for extracting high yield of intact proteins and further hydrolysis from the selected waste streams (rapeseed press cake, mushrooms and leek) were developed. The full process consists of two parts, being (1) the intact protein extraction (2) an enzymatic hydrolysis in to produce protein hydrolysates. The methodologies and approaches tested have been selected according to the following criteria: i) mild working conditions to avoid protein degradation; ii) suitability, taking into account cell wall composition; and iii) material and energetic requirements, following the principle of low energy and materials consumption. Main results can be summarised as:

- for Rapeseed press cake, the extract at pH 9 has been selected. The highest yield of hydrolysis was found with pepsin.
- for Leek and Mushroom, approaches tested gave low yield of hydrolysis
- Yogurt and Milk whey for obtaining antimicrobial peptides. The highest yield of hydrolysis was found with pepsin.

The most promising peptides were on one hand rapeseed press cake for antioxidant and anti-inflammatory peptide, on the other hand mushroom and leek for antimicrobial peptides

None of the predicted peptides based on informatics tools was present in significant amount in the preparations. The characterisation showed that protein extract of Rapeseed press cake has the highest antioxidant activity compared with the hydrolysates showing that probably a non-proteic compound presents also antioxidant properties. Protein extract of Rapeseed press cake have the potential to improve the gastrointestinal health due to their antioxidant potential. In addition, the antioxidant actives are able to pass the gastrointestinal barrier which indicates that they can exert its positive benefits not only in the gastrointestinal gut but also at a systemic level. Additionally, yogurt hydrolysate has antimicrobial activity against E. coli K88 and, as expected, the activity is dose-dependence. The antimicrobial activity is lost during the lyophilization process showing that some kind of protection of the active is needed, for example microencapsulation.

For the production of functional direct extracts, based on the composition (in casu crude protein, crude fibre, crude fat and polyphenol content) several extraction technologies and approaches have been performed: ethanol/chloroform extraction procedure, pH based extraction procedure and methanol based extraction procedure. Innovative techniques, such as SC-CO2 and ultrasound extraction did not yield good results.

Main results are:

- defatted Cheese residue: 74 % of protein
- ethanol/chloroform solvent fraction of Olive pomace: polyphenol content: 9,3 % and ORAC value: 105 µmol TE / g
- methanol extract of Cheese : polyphenol content: 5,0 % (synergistic action with high fat of content 44,0 % of NOSHAN product)
- other potential fractions from NOSHAN products are the ethanol/chloroform fraction of brewing cake and the methanol fraction of Rapeseed.

The results showed that the tested bioactive substances have the potential to exert their bioactivity after passing the digestive processes within the gastrointestinal tract and to act at the requested system, being the gastrointestinal microflora or the animal itself. Out of the simulation trials, the solvent fractions of cheese, sauerkraut as well as olive pomace have the potential to improve the gastrointestinal health.

Finally, the valorisation of residual fractions after recovery of feed additives was studied with the aim to indentify the most appropriate valorization technology. The following residual fractions were assessed: sugar beet flakes, sour cabbage, olive pomace, cheese, leek and rapeseed press cake residue leaves residues. The samples were physico-chemical characterised (water content, ash and volatile content, fixed carbon, nutrients and heavy metals, elemental analysis. They were also characterized for the main fractions (protein, fat and oil and fibers and carbohydrates content), the energetic potential (lower and higher heating values) and the antimicrobial properties. The potential routes for valorization are described below:

- Reuse as bulk ingredients of feed additives: The results showed that sour cabbage and olive pomace show high content of carbohydrates, so they could be applied as a substitute for fibres or sugars in animal feeds. Cheese residual fraction has a balanced composition (64 g/100g protein, 42 g/kg carbohydrates and 96 g/kg fats) and therefore, has the potential to
substitute conventional nitrogen sources on animal feed.

- Fertilizer production using anaerobic digestion and/or composting: Olive pomace is the only substrate with a certain potential use for anaerobic digestion without the need for a co-substrate. The remaining wastes (rapeseed press cake, olive pomace, sour cabbage, sugar beet flakes and leek leaves) cannot be used as sole substrates for anaerobic digestion unless they are co-digested with other substrates. Residues with low water content such as sour cabbage, olive pomace and cheese can be used through other biological valorization routes to produce fertilizers such as composting processes.

- Materials for energy recovery: Values of HHV and LHV show that Cheese, Olive Pomace, Rapeseed and Leek have a high energy content equivalent or higher than woodchips (around 18 MJ/kg). These materials have potential to be valorized by recovering energy. Sour cabbage, cheese and rapeseed has a high Sulphur content (%) that contributes to a high generation of SO2 when are combusted in a conventional biomass boiler. Considering emission limits by current regulation (such as RD 430/2004), a desulphurization system would be required or a co-combustion together with coals is suggested.

- Cosmetic applications: Cheese residual fraction, due to the protein content, can be in cosmetic of the skin since proteins, peptides and amino acids (especially serine, treonine, alanine and piroglutamic) are the main components of the Natural Moisturising Factors (NMF) of the skin. Finally, carbohydrate rich fractions (sour cabbage and olive pomace) can be used as stabilizers and also can contain NMFs. However, the metal content of the fractions (Cr and Ni) exceeds the limits for cosmetic products according to the European Regulation. In addition, high levels of Pb were detected in sugar beet cake residue. Additional characterization of other batches should be considered in order to determine if the presence of these metals are due to sporadic contamination.

As conclusion, in the WP4 all the work performed was achieved properly, specific functional additives were obtained from the waste streams selected in WP2 and WP3. Extraction of these functional additives was carried out with different extraction processes. Functional fibres, functional hydrolysates and bioactive ingredients were produced during the WP. Molecular characterization was analysed and functional demonstration was performed with in vitro models. The most interesting functional additives were selected for the WP5 and WP6.

WP5: Feed production (influence of feed matrix)

The main objective of WP5 was to work on the production of feed from stabilized wastes (WP3) and also considering the functional ingredients from waste origin produced at WP4. These included i) obtain well balanced blends from co-stream substances and key additives with focus on physiological needs of targeted animals; ii) assess the stability of feed by performing adapted technological trials and to evaluate the most promising incorporation strategies via extrusion and co-extrusion and comparison to more traditional technologies; iii) adapt the planetary roller reactor equipment conditions in order to maximize the availability of stabilised substances and key additives via encapsulation to benefit from its technical advantages in feed production; iv) achieve maximum safety and quality parameters by assessing the pre-production prototypes against biological, physico-chemical and toxicological assays.

Bulk feed materials were selected based primarily on their nutritional value in context of animal needs. The other important selection criterion, which was taken into consideration, was the absence of contamination risks within these co-streams. According to literature references, the possible losses of functional ingredients of the bulk materials caused by extrusion are limited. A lower intensity of extrusion reduces degradation-reactions. A planetary roller extrusion creates the possibility to conduct the extrusion process under “mild”.

The abovementioned bioactive additives were selected based upon their different bioactivities such as antioxidant, antimicrobial, agglutinant and anti-inflammatory capacities.
For most of the NOSHAN waste streams it was possible to create diet formulas. This indicates that the waste streams do possess enough energy and/or protein to replace conventional raw materials used in animal diets in a cost-effective way. The requirements were met, because a good dosability and miscibility of the materials were fulfilled. For the development of the broiler and pig feed formulations, a feed calculator based on analyses results of the bulk feed materials, respectively the main functional ingredients, was devised. The next step was the development of formulations performed by Linear Programming (Mix manager). Including conventional formulation ingredients such as cereals and legume products, dietary formulas for the most NOSHAN waste streams were created.

Based on the potential formulations different process strategies in order to incorporate the selected bulk feed materials and feed additives were evaluated, to assess the most favourable upstream and downstream technological processes for obtaining harmonised nutritional and functional characteristics for the final feed products. After performing the targeted combinations of downstream procedures, a technological setup was selected, for scale-up to be following in WP6. The key performance indicators of the resources for processing by Planetary Roller extrusion as main process and the upstream processes like milling, weighing, dosing and downstream processes like drying and milling were developed and characterised.

Formulations of the by-products based upon performed studies on the solvent extract from olive pomace, the solvent extract of sauerkraut, the solvent extract of cheese, fractionated sugar beet pectins and protein extract of rapeseed press cake. The most promising formulations in terms of stability, bioavailability and estimated processing were identified. Since stability and bioavailability of all NOSHAN bio-active fractions posed no problem in the gastrointestinal simulation. The solvent fractions of olive pomace, fractionated sugar beet pectins and protein extract of RPC were retained as candidates for the animal trails in WP7 “Efficacy studies in animal trials”.

To sustain the stability and bioavailability of the functional ingredients of the bioactive additives two strategies worked out to protect them, via microencapsulation and macroencapsulation through extrusion. Both processes were suitable for encapsulation for the protection of sensitive bioactives, albeit they have advantages and disadvantages. An advantage of the macro-encapsulation via extrusion is that large amounts can be processed at low cost. The granules produced can be configured differently (particle size, shape, etc.). A disadvantage is the thermal stress during extrusion and a relatively high proportion of matrix material. The microencapsulation requires a greater effort for the encapsulation of larger quantities. Nevertheless, for those labile bioactives which are susceptible to degradation at environmental conditions of extrusion (oxidative degradation, hydrolysis, thermal degradation...) the microencapsulation offers a valuable alternative. The procedure itself is very gentle compared to macro-encapsulation.

In the specific case of rapeseed extract, microencapsulation in starch matrices showed astonishing synergistic effect by enhancing its bioactivity antioxidant property after in vitro digestion. These remarkable results led to conclude the suitability of microencapsulation of bioactives by the added value offered and encourage the performance of further studies in this line.

The study of the microbial contaminants in the semi-finished and finished products has been assisted during the development of the end-product treatments. To define their full safety appropriateness for animal trials in terms of microbiological and physicochemical cleanliness different analyses for detection were used. The results of these analyses revealed no spoilage or potential contamination from compounds having negative or harmful physiological effects.

The pesticide content of the bulk feed ingredients was below the quantitation limit. In the case of the mixtures, most of the values determined with GC-MS/MS were below the detection limit. The values determined via LC-MS/MS showed residues of chlorpyrifos-methyl and piperonyl butoxide for all the feed mixtures. Both substances are used for the treatment of cereals. This suggests that single cereal-based ingredients within the mixtures probably caused the incidence of these pesticides. Mycotoxin content from the original food seems to be a limited problem, whereas a risk for mycotoxin contamination after wastage and/or processing is possible (as demonstrated by the OTA found in pumpkins), outlining the need of a strict mycotoxin control for the feed ingredients obtained.

Regarding microbiological toxicity, the total mesophilic aerobic, moulds, E. coli and Aspergillus results are used as hygienic indicator microorganisms of processes and raw materials used in the manufacturing. The results obtained for these microorganisms indicated that some samples haven’t been manufactured with correct conditions or maybe the raw material...
used had a high microbiological burden.

The detailed molecular characterization of the peptide and protein fraction and pectin fraction of the selected final feeds was also performed in particular performing directed targeted analysis aimed at detecting compounds with functional activity. The protein fraction seemed to be mostly unaffected by the extraction of the ingredient, even if some processes of ingredient stabilization and feed formulation seem to induce amino acid racemization. Anyway, protein profile was basically unaffected, indicating that the nutritional value is preserved intact. Functional peptides from dairy can be found also in the final feed formulation, albeit less and in lower amount. Anyway, the final protein profile is mostly determined by the other ingredients used for formulation, rather than for the NOSHAN ingredients.

The results on pectin fraction indicated that pectins are highly reduced in ingredient stabilization and feed formulation. Degree of acetylation and esterification are preserved intact, but uronic acid and neutral sugar composition indicate that the pectin structure underwent strong changes in the process leading to feed formulation, beside a drastic decrease.

As a final conclusion it may declare that a technology was developed to process the selected stabilised NOSHAN ingredients (bulk materials and bioactive additives) to the different feeds with high safety and quality features.

WP6: Process scaling up and feed production for demonstration studies

The main objective of WP6 was to scale up the most suitable technologies for stabilization and conditioning, the bioactive ingredients production and feed production from food wastes (obtained as results in WP3, WP4 and WP5). In this sense, WP6 covers the best-identified technologies in the previous WPs with clear objective of obtaining a convenience feed at the lowest cost, using the low energy for stabilization and efficient production. Within this work package, the particular objective were i) conditioning and stabilization scaling-up; ii) production of feed additives scaling-up; iii) feed processing scaling up and iv) validation of the integrated food waste-to novel feed process and products.

The technologies that were optimised from an industrial point of view were: i) acidification conservation (NS); ii) Refractance Window drying (RWD) (ILVO); and iii) solid content extraction technology (PROVALOR).

Reengineering activities were performed in order to optimise the RWD system. As initial results on this technology, inlet and outlet sections were readjusted compared to the former pilot RWD. These actions allow an easy control of the layer thickness, a relevant parameter during drying.

In the case of acid conservation, it was observed that the addition of sorbic acid and medium chain fatty acid (MCFA) generally had a positive effect. The addition of lactic acid or fumaric acid was generally too weak. The addition of dairy waste to provide organic acids (mainly lactic acid) had no effect.

Regarding to the results of mechanical pressing as a pre-treatment process prior to the stabilization processes, it was found that fresh pumpkin samples are an interesting remnant stream.

Coating techniques optimized in WP5 via extrusion techniques have been evaluated. The conclusions are that coating techniques are not necessary for scale-up procedures of feed additive production. The encapsulation of the bioactives is not necessary according the results obtained in WP6 and previous WPs.

The evaluation of the analysis of ingredients and extruded feeds is carried out for the final prototypes. The results show that no differences are obtained between samples before and after extrusion. The compositional analysis of the extruded feed has confirmed that the compounds present in the additives were stable during the extraction process and they can be successfully transferred to the feed. All the data indicates that the extrusion process does not affect the additives added, preserving intact their structure as it can be found after extraction from the original food waste matrix.

Based on the results of the various technological experiments, the realizable and innovative techniques to optimize the
technological transfer into the industrial scale were selected. Technological procedures have followed standard scaling-up and technology validation protocols according to regular GMP requirements, as described also in the technological descriptions. Quality and high throughput of obtained additives and bulk feed materials were the most important key performance indicators, and as the scale up trials showed, these parameters were largely achieved. The technological steps were assessed against the CCP procedures, thus the most technologies up-scaled have complied also with the HACCP standard requirements.

A preliminary sustainability assessment was carried out under WP6, which considered the information obtained under WP6 as well as from other WPs to provide suggestions for the sustainable feed recipes. Within the context of this assessment, (i) benchmark values were determined, (ii) an initial hotspot analysis was carried out to determine the most dominant feed components creating adverse environmental impacts, and (iii) preliminary LCA results were obtained for bulk ingredients. Results suggested better environmental performance was observed with higher inclusion of NOSHAN streams in feed. 10% NOSHAN mix feed was added to animal trials based on these results.

Taking into account the overall scale-up of technological transfer activities done, we may conclude that the technologies up-scaled were rigorously controlled and complied with the implemented quality checks implemented.

The integration of food waste to feed process means implementation of scale-up procedures for generating compound feed through incorporating feed additives and bulk feed materials into the selected technological processes, rigorously controlled and monitored by the HACCP requirements designed for this specific chain.

By performing the final optimizations, all the technologies of WP6 (pre-treatment, stabilization, coating, incorporation strategies of feed additives, feed additives production and technologies thereof, enzymatic downstream, extraction, upstream enrichment) were again assessed, according to standard procedures, but the emphasis was on the validation of final technological steps in the chain: drying and extrusion, which are the most important in terms of obtaining high throughputs with stable quality of output products. The selected processes are the correct ones, being suitable for feed production.

The processing steps at extrusion and extraction level were both CCP controlled. Thereby the risk of microbiological spoilage and other damages during the manufacturing was reduced. None of the processing steps of feed manufacturing, including the preparation of the additives had any influence on the pesticide nor mycotoxin levels. All ingredients contained pesticides except whey. However, the pesticides were overall below the detection limit, complying with statutory requirements, thus no health hazards arise.

The production of additive from olive pomace (NS), rapeseed press cake hydrolysate (LEITAT) and oligopectinic fibres (VITO) have been carried out. First prototype products of extrudate samples had been developed for each additive (IGV). The planetary roller extruder PWE 70, manufactured by Entex, is very suitable for the production of feed. Owing to a repeated thin-film rolling-out, a precise temperature control and a gentle material processing are possible. The system is hygienically suitable to prepare low-germ products, because it is a fully closed system. Thus the system is very suitable to produce safe compound feed. First extrudates samples with rapeseed press cake hydrolysate, olive pomace extract and sugar beet pectins had been produced.

The next step after performing a first final compound feed technology design and production, which served as basis for the animal trials, was to implement and replicate in a final optimised way the production of integrated feed products containing selected bulk feed materials and feed additives.

The compositional analysis of the extruded feed had confirmed that the compounds present in the additives were stable during the extraction process and they can be successfully transferred to the feed. All the data indicates that the extrusion process did not affect the additives added, preserving their intact structure as it can be found after extraction from the original food waste matrix.
The final validation in terms of microbiological and chemical safety and the quality features after processing and prior to animal feeding trials were dully assessed and aligned to requirements of state-of-the-art standard protocols.

The ESI scan (UPLC/ESI-MS system - UPLC Acquity Waters with a single quadrupole mass spectrometer Waters ACQUITY SQD) of the pectic oligomers had shown the presence of methylated, double methylated, triple methylated and acetylated forms, which are comparatively more present when the hydrolysis is done at higher enzyme concentration. The microbiological analyses showed that the three additives are contaminated with mesophilic aerobic, additionally peptides are contaminated with mould. The European Union with the Regulation (EC) 183/2005 lays down requirements for feed hygiene, but in this regulation there is no legal criteria for bacterial and fungal counts, leaving that these limits are established by producer feed. No pathogen microorganisms are detected in the additives. The pesticides analysis showed that all detected pesticides are below the detection limit for bulk feed material and additives but they are present in very low amounts.

As a final conclusion it may declare that it has been proven that the safety and quality features of the selected NOSHAN ingredients is ensured also at industrial scale, this being the result of the rigorously performed technology transfer protocols.

**WP7: Efficacy studies in animal trials**

The main objective of WP7 was to demonstrate the biological efficacy of the functional feed additives in compound feed produced in WP5 by performing well-designed animal trials in monogastrics. Specific objectives were the following: 1) Test the effect of pig compound feeds enriched with functional feed ingredients to improve performance (growth, feed intake and feed efficiency as well as meat quality), health and welfare of weaning piglets and 2) Test the effect of poultry compound feeds enriched with functional feed ingredients to improve performance (growth, feed intake and feed efficiency as well as meat quality), health and welfare of chickens.

Initially, the protocol for testing the effects of the different functional compound feed derived from waste products produced in WP5 was designed and validated by the independent Ethical Committee. Parameters such as number of animals, treatments, markers, data collection, and data analysis were defined. The animal experiments complied with the ethical standards and guidelines of FP7 and with the revised Directive 2010/63/EU on the Protection of Animals used for Scientific Purposes which will become law (January 1st 2013). Animal trials (pigs and poultry) were designed according to the Description of Work and available housing system and were based on the results obtained from the in vitro work from WP4. Detailed trial protocols were drafted by NS according to the “3R principle” (replacement, reduction and refinement) so that the correct amount of animals is used to meet the set goals with a minimum amount of discomfort for the animals.

Trials were performed according to the following protocol:

- **Piglets**: Sixty-four weaned piglets per group were divided in 16 cages of 4 animals each. Piglets were fed from weaning (21 days old) till 4 weeks after weaning. The control group received a standard diet (no bulk waste stream or functional feed ingredient (FFI)). Animals were monitored daily and fresh feed was provided. Fresh drinking water was provided continuously via the automatic drinker system. Next to standard feed (Weende analysis) and zootechnical (body weight, feed intake, growth and feed conversion) parameters, also parameters concerning gut health (faecal score, bacteriology, intestinal secretion, mucosal immunity and intestinal integrity), animal welfare (clinical score and acute phase proteins in blood), as well as meat characteristics dealing with quality and safety issues (pH & colour changes, protein/fat ratio & fatty acid composition, bacteriology, dioxins & heavy metals, oxidative damage, cholesterol oxidation, organoleptic changes & flavour) were monitored.

- **Poultry**: One hundred broiler chickens per group were divided in 5 pens of 20 birds each. Chicks were raised from day-of-
hatch until slaughter. Daily monitoring of the animals as well as the parameters to be tested were performed analogously as described above for piglets.

Animal trials in weaning pigs aimed at examining the potential beneficial inclusion of both NOSHAN bulk ingredients as well as biofunctional additives in piglet diets. These animal trials were performed at the trial stables of partner NS.

Following most promising NOSHAN bulk feed ingredients to test in piglet feeding trials were selected:
- Yoghurt @ 1.5% (w/w) (hereafter referred to as “YOG”)
- Whey powder & rapeseed presscake (to be used together in a 1/10 ratio) @ 1.5% (w/w) (hereafter referred to as “WR”)
- MIX of these 3 components @ 10% (w/w) (hereafter referred to as “MIX”)

Additionally, quality analyses on NOSHAN bulk ingredients, as well as on piglet feed containing them were performed among different partners. Mycotoxin analysis, protein content analysis and peptide characterization were performed by partner UNIPR, pesticide residue detection by partner IGV and minerals & trace elements and microbiological characterization by partner LEITAT. Finally, a taste panel was included, i.e. triangle tests to check whether control meat can be discriminated from test meat, and affection tests to examine the preference of the panelists. Feeding feeds containing up to 10% of the selected NOSHAN bulk ingredients and extruded by IGV technology did not lead to (significantly) lower animal performance, nor to loss in meat quality and safety in piglets. Pork meat from YOG and CON were best appreciated.

Following most promising NOSHAN biofunctional additive were selected to test in piglets all at a dosage of 500 ppm:
- Sugar beet pectins @ 500 ppm (g/ton of final feed) (hereafter referred to as “SBP”)
- Rapeseed presscake peptides @ 500 ppm (hereafter referred to as “RPCP”)
- Extract of olive pomace @ 500 ppm (hereafter referred to as “OP”)

In terms of animal performance, no statistical differences could be noted compared to the control when animals were fed feed containing NOSHAN biofunctional additives. OP, however, resulted in (numerically) improved body weight in piglets, probably due to a better overall health status of these animals, confirmed by a better intestinal health, as proven by TEER and permeability studies on gut epithelial cells and by a (numerically) lower pathogenic load in the stomach of piglets. However, no statistical differences could be detected.

Animal trials in poultry aimed at examining the potential beneficial inclusion of both NOSHAN bulk ingredients as well as biofunctional additives in broiler diets. These animal trials were performed at the trial stables of NS.

Following most promising NOSHAN bulk feed ingredients to test in piglet feeding trials, were selected:
- Yoghurt @ 1.5% (w/w) (hereafter referred to as “YOG”)
- Whey powder & rapeseed presscake (to be used together in a 1/10 ratio) @ 1.5% (w/w) (hereafter referred to as “WR”)
- MIX of these 3 components @ 10% (w/w) (hereafter referred to as “MIX”)

The addition of NOSHAN bulk ingredients into broiler diets up to 10% and extruded by IGV technology does not lead to reduced performance. Inclusion of 10% NOSHAN bulk ingredients even led to (numerically) improved body weight and feed conversion. But no significant differences could be detected. In addition, using NOSHAN bulk ingredients may be interesting in terms of meat quality and stability, due to the higher accumulation of omega 3 fatty acids EPA and DHA, implicated in improving human health, as seen for the MIX group. Feeding NOSHAN bulk ingredients to broilers will not lead to loss in meat safety. Taste panel revealed a significant difference between chicken breast meat fed the control diet compared to the WR and MIX diet. However, neither group was preferred over the other.

Following most promising NOSHAN biofunctional additives were selected to test in broilers all at a dosage of 500 ppm:
- Sugar beet pectins @ 500 ppm (g/ton of final feed) (hereafter referred to as “SBP”)
- Rapeseed presscake peptides @ 500 ppm (hereafter referred to as “RPCP”)

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In terms of animal performance, no statistical differences could be noted compared to the control when animals were fed feed containing NOSHAN biofunctional additives. OP, however, resulted in (numerically) improved body weight in broilers, probably due to a better overall health status of these animals. This was confirmed by a better intestinal health, as proven by TEER and permeability studies on gut epithelial cells and by the (numerically) reduced presence of stress proteins in the blood of chickens. However, no statistical differences could be detected.

To conclude, the tested bulk feed ingredients could be used in the animal diets without harming technical performance and quality of the resulting meat. Some biofunctional additives, such as OP, tended to increase zootechnical performance in both pigs and poultry, probably by the antibacterial effect resulting in better gut health.

**WP8: LCA and legislative framework**

The main objective of WP8 was to carry out the environmental evaluation of NOSHAN Project, using Life Cycle Assessment (LCA) tool, of feed production from food waste following NOSHAN approach. Main activities of WP8 were i) environmental assessment of NOSHAN outcomes through life cycle assessment (LCA), ii) validation of innovative feed processing techniques by means of Environmental Technology Verification (ETV) of refractance window drying (RDW) and iii) ensuring the compliance to EU regulations during project activities.

Activities under WP8 have close ties with WP5, WP6, WP7, and WP9. A preliminary LCA study was carried out under WP6 with information obtained under WP5 and WP6. Based on the preliminary assessment, 10% NOSHAN mix is introduced to the animal trials in WP7. Based on the data from animal trials (WP7), bioactive production (WP6), and energy performance of innovative feed processing techniques (WP6), a detailed LCA study was conducted. Both LCA and ETV activities are important means of dissemination of NOSHAN Project in WP9.

The goal of the full LCA study under WP8 was to quantify the cradle-to-gate environmental impacts of feed manufacturing in two monogastric (broiler and pig) feeding systems. The system boundaries, selected as cradle-to-farm, consider crop production activities, dairy processing, feed mill operations, chemical manufacturing processes in the foreground and transportation and electricity generation in background. Life cycle impacts of the reference conventional feed value chain and NOSHAN feed value chain were assessed based on two functional units; per kg of feed and per kg of live weight gain by the animal in farm. Relevant impact categories for the full LCA is determined as climate change, agricultural land occupation, natural land transformation, water depletion, toxicity, fossil fuel depletion, acidification, eutrophication. For the life cycle inventory, in addition to datasets developed under NOSHAN project, data obtained from Ecoinvent 3.01 and AgriFoodPrint databases were used.

A very detailed assessment was carried out for NOSHAN to identify the life cycle impacts of feed recipes developed for the project and compare them with traditional feeds. Under the NOSHAN LCA study, 72 models were created for various feeding stages of piglets, which were fed with 3 alternative NOSHAN feeds. For broilers, this number reached to 144 models.

For broilers the hotspots are identified as soybean production in South America, electricity, and transportation. In addition to these, amino acid and feed crop production in the EU create high levels of environmental impacts for the piglet cases. The results showed that the NOSHAN diets that include the agricultural and dairy processing residues enhances the environmental performance of the broiler and piglet feed chains. In accordance with the results of preliminary sustainability analysis, 10% NOSHAN mix (bulk ingredients) exhibit the lowest environmental impacts in terms of natural land transformation, human and environmental toxicity, global warming potential, agricultural land occupation, which are identified as significant environmental impacts of feed supply chains in European context. These environmental benefits originate not only from
substitution of key feed ingredients in terms of adverse environmental consequences but also from improved energy performance of feed processing technologies including planetary roller extruder and refractance window drying. Furthermore, some feed recipes were able to decrease the amount of feed consumed for each kg of live weight gain by animals in the farm. No significant differences were observed between the cases with and without NOSHAN functional additives.

NOSHAN approach on the hand, valorize agriculture and dairy processing residues by replacing mainly soybean in the feed. For every kg of broiler feed, carbon dioxide emissions are reduced by 0.3 kg CO2-eq with 10% NOSHAN mix diet. Assuming 1% of total broiler feed can be switched to 10% NOSHAN mix, this means a total avoidance of 0.62 million tons of CO2 emissions to the atmosphere each year. By reducing the amount of soybean used for the piglet and broiler diets, NOSHAN Project decreases the soy dependency of European feed industry. Furthermore, NOSHAN offers an alternative approach for feed production to alleviate the social burden of feed industry. Use of agricultural and dairy processing residues would also help to maintain the feed cost comparable to conventional soybean rich feed recipes.

The implementation of the EU Environmental Technology Verification pilot programme on one of the technologies well developed in the project, fits with the requirements of this kind of assessments.

The concept of the ETV programme is to offer a verification procedure to cutting edge environmental technologies that may otherwise find it difficult to establish their environmental added value. The verification procedure allows for an independent assessment and validation of the manufacturer's claims on the performance and environmental benefits of their technology. ETV results could be used to prove compliance with any relevant legislation, to underpin a bid in public tendering, to convince investors or customers of the reliability of performance claims and to avoid having to repeat demonstrations for different users. Initially, the ETV scheme covers the following technology area: i) Energy technologies; ii) Water treatment and monitoring technologies; iii) Material, wastes & resources technologies (EU Environmental Technology Verification. Pilot Programme, 2016). The NOSHAN project is located in the third category. According to the technologies developed during the project, the refractance window drying (RWD) (by ILVO) has the best profile for such verification. For this assessment, the following performance claims were choosen: energy efficiency of the RWD; ability of the RWD to maintain colour of initial feed material; and minimal solids yield loss. This evaluation was performed by RINA (evaluation body) in collaboration with ILVO and G3 enterprises (owner of the technology patent).

The verified average thermal energy consumption resulting higher than the claimed range. The test results show a colour loss value slightly bigger than expected, however, Extinction Value (EV) on a dry basis at (λmax) of the products was in line with the expected performance. It means that the colour intensity meets the performance claimed and the colour loss value is only due to the higher value of the dry mass based material (DMB). Finally, the drying process of the tested products does not involve any significant dry product loss, with a solid yield bigger than 96,6% at the 95% confidence level.

NS evaluated regulation compliance of the bulk feed ingredient dried yoghurt (as designed by partner ILVO), dried fresh pumpkin (as designed by partner ILVO), dried rapeseed press cake (as designed by partner IGV) and whey (as designed by partner IGV) as well as the functional feed ingredients based on solvent extract from olive pomace (as designed by partner NS), the solvent extract of sauerkraut (as designed by partner NS), the solvent extract of cheese (as designed by partner NS), fractionated sugar beet pectins (as designed by partner VITO) and protein extract of rapeseed press cake (as designed by partner LEITAT). The NOSHAN project aims to develop NOSHAN outcomes that are in line with legislation, making implementation of them into feed industry possible. This task shows the coordination and match of the outcomes with the legislation (status November 2014, and based on the 5 basic regulations, animal protein legislation and the law on undesired substances) and related institutes such as FEFANA, FEFAC, EFSA and the European Commission.

All NOSHAN products are allowed in today’s animal nutrition, except for sauerkraut, that is only allowed after - easy ! - registration in the feed material register. However, in WP7, sauerkraut and cheese concepts were skipped for testing in animals, because from WP4 it is clear that the solvent extract of olive pomace is more promising than sauerkraut and cheese
derivatives. This way, it was possible to validate all NOSHAN outcomes in the animal trials in WP7 “Efficacy studies in animal trials” for demonstration the efficacy of the respective NOSHAN outcomes in terms of animal performance, health and wellbeing.

WP9: Dissemination and exploitation activities

Disseminating the information and results of the project within the partners and outside the Consortium, as well as proposing exploitation transfer plans and managing the Intellectual Property Rights have been the two focuses of the dissemination and exploitation activities carried out during NOSHAN project. Starting with the dissemination activities performed, KIM has organized those activities in order to cover the main relevant aspects on dissemination of this kind of project counting with the collaboration of the whole consortium.

The first set of dissemination activities have been the creation of promotional and advertising materials, with the goal of exploiting: the knowledge regarding valorisation paths for industrial fruit and vegetable applications as well as dairy processing wastes in industrial food and livestock sectors; and all possible industrial outcome for the research “products” developed during this project.

- NOSHAN’s website (www.noshan.eu) was created in line with the NOSHAN identity and has been continuously updated with content. The private part has been used as a repository of documents for the consortium. Recently, the food waste database obtained within the project has been published there as well. The web will be fully operational until one year after the end of the project. The indicator of success was to reach the number of 5000 unique and at 31st January 2016, the number of visitors has been 7381.
- The objective of creating a project newsletter is to maximize the dissemination of the results and create opinion on the mains theme related to the project. This has been the purpose of each of the newsletters sent every 6 months during all the project (5 in total).
- Nowadays, one of the most effective ways to disseminate to the general public the results of a project is a video that explains briefly and in a friendly way the project objectives, main results and impacts. This video can be seen following this link: http://bit.ly/NOSHAN_Video
- The printed materials that can be used to disseminate a project are diverse and each material has a different purpose. KIM has designed a set of materials covering different needs: project leaflets and posters, merchandising materials for events such as a folder, a notebook and a pen, and infographies to transmit in a visual way the main outcomes of the project.

The second set of dissemination activities have been centered in the communication to external stakeholders and all consortium has been involved.

- Five scientific publications already published (Müller-Maatsch et al 2014; Babbar et al 2016; Babbar et al 2016; Judith Müller-Maatsch et al 2016, Babbar et al 2016), plus a chapter in a book. In addition, two more publications are in preparation. This proves the quality of NOSHAN research activities and the interest that the scientific community has for them. Moreover, 2 publications for the general public and 9 press releases show that the consortium has made an effort to transmit the project results to the general public.
- All partners have contributed in the 97 presentations of NOSHAN to national and international forums through oral and poster presentations. Moreover, the Euronews TV has filmed a documentary about NOSHAN.
- The organization of two international workshops has allowed the consortium to share the project results with different groups of stakeholder.
- The effectiveness of social networks to disseminate any kind of information is undeniable and NOSHAN’s linkedin, facebook and twitter profiles have helped on dissemination.
- Coordination with other projects: the main projects with whom NOSHAN has established a collaboration relationship have been: FUSIONS, REFRESH, TRADEIT, APROPOS, CYCLE, HEALTHY MINOR CEREALS and SUNNIVA.
Continuing with the exploitation activities performed during the project, according to the market analysis carried out, there is a clear market need of solutions such as NOSHAN’s. All the three main sectors of application (Feed, Food and Organic waste management) are considered target and susceptible for a technology transfer strategy. They can take great advantage from the project’s results, increasing their competitiveness.

Each technology developed during the project has been identified and analyzed in order to define an exploitation strategy that can maximize the return on investment of each output of the project. Six exploitable technologies have been identified and a strategy of exploitation has been proposed and it will be carried out by the partners, owners of these technologies jointly with other partners that have interest in using these results.

- The Planetary-Roller Extrusion (developed by IGV)
- The Refractance window drying (developed by ILVO)
- The Production of bioactive peptides by directed hydrolysis of protein rich wastes (developed by LEITAT)
- The Hydrolysis of protein rich wastes to improve digestibility (LEITAT)
- The Ultrasound and/or assisted protein extraction (LEITAT)
- The Tailored production of Pectin oligosaccharides (POS) by coupling of hydrolysis and separation (developed by VITO in collaboration with UNIPR)

Information regarding the technology definition, the technology competitiveness and the Intellectual Property status was compiled. With this information, a strategy of exploitation has been proposed and it will be carried out by the partners, owners of these technologies jointly with other partners that have interest in using these results.

Moreover, regarding the evaluation of technologies, a collaboration has been established with ProBIO project (Professional support to the uptake of bioeconomy RD results towards market, further research and policy for a more competitive European bioeconomy - http://probio-project.eu/). This project funded by the European Commission, is a CSA (coordinated and support action) of H2020 that started on March 2015. All partners belong to the Greenovate Europe Network. The reasons for collaborating with ProBIO are the services they offer to the KBBE projects such as NOSHAN:

- Coaching for market uptake
- Tailored support for further R&I
- Networking and knowledge exchange

In order to:

- To increase the opportunity for KBBE projects to reach the market, by facilitating links to industrial and financial investors.
- The most mature KBBE results will be coached to market uptake in the form of start-up creation or licensing deals to industrial players.
- ProBIO will also provide guidance and support on how to exploit KBBE knowledge through further applied research, to feed policy making and implementation.

The ProBIO team experts have analysed NOSHAN technologies and have selected them all for their coaching activities that will be performed during 2016.

As a conclusion, the diversity of dissemination activities performed within WP9 has allowed the main objective of reaching different types of audiences and creating awareness within all of them at the different stages of the project development until the end, which is a key factor to promote the exploitation of the project results. It has to be highlighted that it has been the hard work of the scientific partners that has given as a result, the 6 technologies that have been developed within NOSHAN. KIM has given our expertise in order perform a market research and a technology analysis that helped defining the time to market of each technology. Each technology has different characteristics and different time to markets but all of them have interesting possibilities of being exploited.
Global meat production has tripled in the past three decades and could double its present level by 2050 (Stanford New, 2010. New report reveals the environmental and social impact of the ‘livestock revolution’). Production of animal feed consumes about one-third of total arable land (Stanford New, 2010. New report reveals the environmental and social impact of the ‘livestock revolution’). Livestock production accounts for approximately 40 percent of the global agricultural gross domestic product (Stanford New, 2010. New report reveals the environmental and social impact of the ‘livestock revolution’). Production of livestock and feed supply chains are tied to a variety of environmental impacts including consumption of resources, alteration of ecosystems, greenhouse gas emissions, land degradation, water depletion and pollution.

In 2007, 35.8 million tons of soybean meal and 3.5 million tons of soy oil was consumed for feed production. Agricultural land dedicated to feed-crop production, in particular the land utilized for growing maize and soybean in South America, is rapidly expanding in order to satisfy the demand. Soy production can cause greenhouse gas emissions, including carbon dioxide from fossil fuels, deforestation, and emissions from soil management and tillage practices.

Environmental, social and economic impacts of global feed value chain are closely interconnected. Feed industry is mainly driven by the meat consumption and nutritional requirements of the growing population. Price is extremely important as animal feed is consumed in large quantities and a small price difference can have major consequences, especially for SMEs. Economic considerations are among the priorities and EU feed industry is facing the challenge to stay competitive while establishing sustainable practices as a standard. To meet this challenge, not only environmental status in Europe but also global impacts needs to be considered.

NOSHAN Approach on Sustainability: A Life Cycle Perspective

Reducing the overall impact over the feed supply chain is challenging in particular due to the use of high impact feed-crops and highly processed feed ingredients. During NOSHAN project, a combination of yoghurt, rape seed press cake and whey powder was introduced to broiler and piglet diets up to 10% by weight in order to replace these feed constituents. Development of new feed recipes in NOSHAN project was supported by a two-stage sustainability assessment. In the preliminary assessment part, a screening life cycle assessment (LCA) study was undertaken. The results of this initial assessment indicated that the reduction in environmental impacts are higher for feed recipes containing higher quantities of agricultural and dairy processing wastes. This observation lead to inclusion of 10% NOSHAN mix, which contains 5% of yoghurt and 5% of rapeseed press cake and whey powder mixture.

The outcomes of the NOSHAN project was evaluated with a cradle-to-farm gate LCA at the end of the project. This LCA study quantified the environmental impacts of NOSHAN feed and compared them with traditional feed diets based on per kg of feed and per kg of live weight gain by the animal in farm. The environmental impacts were assessed considering the effects of NOSHAN approach in terms of climate change, agricultural land occupation, natural land transformation, water depletion, human and ecotoxicity, fossil fuel depletion, acidification, and eutrophication. Three scenarios based on the NOSHAN feed recipes used in the animal trials were handled and compared with traditional feed diet (control) for bulk ingredients and bioactives each. The scenarios for bulk ingredients included a 10% NOSHAN mix (5% Yoghurt and 5% RPC+whey powder mixture), 1.5% Yoghurt, and 1.5% RPC+whey powder. Bioactives considered for the LCA were olive pomace extract, rapeseed hydrolysate, oligopectins from sugar beet pulp.

For the life cycle inventory, in addition to datasets developed under NOSHAN Project, data obtained from Ecoinvent 3.01 and AgriFoodPrint databases was used. According to the hot spot analysis conducted, major contributors to the environmental impacts within the broiler feed were soybean products from South America, electricity consumption, and transportation. In addition to soybean products from South America and electricity consumption, production of feed-crop (such as wheat, corn and barley) within the EU and amino acids within the diets were observed to create high level of environmental impacts in the case of piglet feeds. Therefore, it can be deduced that replacement of high impact feedstuff with agricultural and dairy processing residues lower the environmental
footprint of feed. The impact assessment results showed that the NOSHAN diets that contain agricultural and dairy processing residues enhances the environmental performance of the broiler and piglet feed chains. 10% NOSHAN mix creates less environmental impacts not only in comparison to traditional control feed but also to yoghurt and combination of RP+WP. This diet exhibit the lowest environmental impacts in terms of natural land transformation, human and environmental toxicity, global warming potential, agricultural land occupation. Reductions in environmental impacts are (i) natural land transformation: >30%, (ii) human toxicity, non-cancer: 20%, (iii) ecotoxicity: 18%, (iv) global warming potential: 15%, (v) agricultural land occupation: 12% in comparison to control feed use in Animal Trials of the NOSHAN Project. These environmental benefits originate not only from substitution of key feed ingredients in terms of adverse environmental consequences but also from improved energy performance of feed processing technologies including planetary roller extruder and refractance window drying. It is observed that up to 30% energy reduction is possible after optimization of planetary roller extruder and RDW technologies. Furthermore, some feed recipes were able to decrease the amount of feed consumed for each kg of live weight gain by animals in the farm. Lower the amount of the feed needed during the farm phase, lower the overall environmental impacts. NOSHAN approach on the hand, valorize agriculture and dairy processing residues by replacing mainly soybean in the feed. For every kg of broiler feed, carbon dioxide emissions are reduced by 0.3 kg CO2-eq with 10% NOSHAN mix diet. Assuming 1% of total broiler feed can be switched to 10% NOSHAN mix, this means a total avoidance of 0.62 million tons of CO2 emissions to the atmosphere each year. By reducing the amount of soybean used for the piglet and broiler diets, NOSHAN decreases the soy dependency of European feed industry. Furthermore, NOSHAN offers an alternative approach for feed production to alleviate the social burden of feed industry. Use of agricultural and dairy processing residues would also help to maintain the feed cost comparable to conventional soybean rich feed recipes.

Impact on scientific community

LCA methodology utilized to support feed recipe optimization and assess the environmental performance of the broiler and piglet diets under NOSHAN provides a holistic and inclusive method to evaluate a broad range of possible impacts. A very detailed assessment was carried out for NOSHAN to identify the life cycle impacts of feed recipes developed for the Project and compare them with traditional feeds. Under the NOSHAN LCA study, 72 models were created for various feeding stages of piglets, which were fed with 3 alternative NOSHAN feeds. For broilers, this number reached to 144 models. NOSHAN LCA study not only brought an interdisciplinary group of experts but also provided meaningful outputs that can be easily communicated to many stakeholders within and outside the scientific community. It is also a reference study to all researchers concerned with the life cycle impacts of agricultural residues, feed value chain and livestock industry.

Main dissemination activities and exploitation results

Coordinating the dissemination and the exploitation activities, might seem some times hard within a project, given that most of the results are confidential and disseminating them can seem counter-productive. Nevertheless, a new vision in this regard is required if we want to increase the impact of our projects. Creating awareness of a project during all the different stages, addressing different messages according to the type of audience, availability of results and respecting the confidential agreements is a key activity to promote the exploitation of results and therefore, the impact that the project outcomes can have.

As mentioned before, KIM has organized the dissemination activities in order to cover the main relevant aspects on dissemination of this kind of project counting with the collaboration of the whole consortium. The two main principal sets of activities have been:
1. Creation of promotional and advertising materials
   a. Website
The activities performed, the indicators of success used and the impact achieved are summarised here:

Activity: Website
Indicator / criteria of success: Number of connection to the website: 5.000 unique visitors by the end of the project.
Impact achieved:
• Periodic update of content during all the project.
• Number of unique visitors during all project: 7381

Activity: Newsletter
Indicator / criteria of success: Number of stakeholders covered by newsletter mailing.
Impact achieved:
• 5 newsletters released
• Newsletter sent to 23 NOSHAN partners + 73 stakeholders specific from NOSHAN project + 61 stakeholders from public administrations + 50 contacts from R&D directors + 1005 companies
• Average open rate: 18%. Note: Average in the topic Agriculture and Food services (25.33%)

Activity: Video
Indicator / criteria of success: Number of stakeholders to which the video will be presented.
Impact achieved:
• From 31st January, the video has 60 views on KIM’s YouTube channel.
• Each partner will disseminate it through their own networks.

Activity: Materials
Indicator / criteria of success: Coverage of all targeted stakeholders and multipliers of the target-groups.
Impact achieved:
• General public targeted with the generic leaflet and poster at general events such as the KIM conference organised by KIM and through the website.
• Scientific public targeted in events with the pack of material for events like the infography summarising results.

Activity: Scientific publications
Indicator / criteria of success: High Impact index of the publications
Impact achieved:
Activity: Presentation to national and international forums  
Indicator / criteria of success: Number of participants (in total) participating to the Scientific Congress.
Impact achieved:

Number of presentations of the project in different forums: 97

Average number of participants:
- Workshops: 20 - 50 participants
- NOSHAN events: 50-100 participants
- Regional scientific conferences: 20 – 50 participants
- National scientific conferences: 50 – 500 participants
- Scientific conferences: 1000 – 4000 participants

Activity: Event organisation  
Indicator / criteria of success: Number of participants (in total)
Impact achieved:
- Number of participants in 1st event: 102
- Number of participants in Final event: 44

Activity: Social networks  
Indicator / criteria of success: Number of followers
Impact achieved:
- 331 followers on Facebook, 51 on Twitter and 28 in LinkedIn group.

Activity: Coordination with other projects  
Indicator / criteria of success: Number of projects
Impact achieved:
- 7 projects: FUSIONS, REFRESH, TRADEIT, APROPOS, CYCLE, HEALTHY MINOR CEREALS and SUNNIVA.

Regarding the exploitation activities, in order to ensure that the R&D developments of a project have an impact, it requires not only the obvious research development but also the analysis from a market point of view, in order to map the project outcomes onto the actual market needs and realities. KIM has followed a process for the technology assessment involving several activities:

1. Technology evaluation
   a. Compilation of all the information related to all the exploitable results / technologies within the project.
   b. Evaluation of the technologies arising from NOSHAN project according to market criteria
   c. Priorisation of technologies in order to position the technologies and products on the market and define which technologies are closer to the market.
   d. Preparation of a roadmap for those technologies to reach the market.
2. Technology valorization
   a. Market analysis
   b. Environmental analysis through the PESTLE - analysis of the Political, Economical, Sociological, Technological, Legal and Environmental factors that can affect the project.
   c. Analysis of the legal framework affecting the feed and food sectors
   d. Analysis of the competitive position of NOSHAN outcomes through the analysis of what the competence is doing from a scientific (publications) and market (patents) point of view.
3. Preparation of an exploitation plan in collaboration with R&D and Industrial partners in order to propose the best exploitation of all the results from the project according to a properly protection of them.
Regarding the technology evaluation and valorisation, according to the market analysis carried out there is a clear market need of solutions such as the ones offered by NOSHAN. All the three main sectors of application studied (Feed, Food and Organic waste management) are considered target and susceptible for a technology transfer strategy. They can take great advantage from the project’s results, increasing their competitiveness. The fragmentation of most of them presupposes a driver for the inclusion of new technologies and innovative processes.

Regarding these sectors, the exploitation strategy sets a prioritization based on what the main focus of the project is because this can affect directly the impact that the project can have.

- The feed industry is regarded as the first target sector for the exploitation. There is a lack of raw material and proteins in the European market, which leads to import them from other countries and to a consequent loss of competitiveness for the European companies; NOSHAN can help to significantly improve the whole sector. This industry could include the NOSHAN’s results directly in its value chain, as the project’s output directly match with the final products that companies operating in this sector offer to their customers (feed and feed additives).

- The food sector is considered secondly, in particular fruit & vegetables and dairy industries that suffer greatly from loss and waste. In the case of companies in this industry, incorporating NOSHAN’s results would represent a change of value chain with a valorization of their waste and an expansion of their business model. Investment in this sector to expand the business model would be higher than in the feed industry, but the project's results offer these companies the possibility to create a new profitable business unit and, at the same time, boost sustainability of their core business.

- As a third option, the market for organic waste management is considered. It is considered that companies operating in this sector are already betting on a revaluation of organic waste, but the trend is to monetize the business model through the development of “bioenergy” products (new bio-fuels such as bioethanol or biogas) or compost. NOSHAN will explore where the valorisation will be competitive compared to other possible valorization routes.

Moreover, each technology developed during the project has been identified and analyzed in order to define an exploitation strategy that can maximize the return on investment of each output of the project.

Six exploitable technologies that could have an impact in the food/feed and organic waste management sectors have been identified and a strategy of exploitation has been proposed and it will be carried out by the partners, owners of these technologies jointly with other partners that have interest in using these results. A brief summary of the technology analysis is provided below:

- The Planetary-Roller Extrusion (developed by IGV) technology is a special kind of extrusion based on the common process that allows to transmit only the necessary amount of a product-specific mechanical and thermal energy to the raw materials. During the project, IGV has implemented substantial improvements to this technology and so far, its applicability has been considered in the food and feed sectors. Thus, feed or food processors are the targets for the technology innovation carried out by IGV. IGV is already on the move for exploiting this technology through licences to third parties.

- The Refractance window drying (developed by ILVO) technology to stabilize dairy or plant-based food wastes is a thin film drying technique, suited to dry liquid or semi-liquid foods. It is an innovative, energy-efficient, self-limiting thin layer drying method, for continuous operation which maximally preserves the initial quality of the feedstock. Commercial systems at TRL 9 level are available from G3 enterprises (USA) and the technology is patented in USA but not in Europe where ILVO is trying to commercialize it. ILVO has provided great improvements to the technology which has applicability in the food waste and feed sectors. For this reason, its main potential acquirers should be found in the feed sector.

- The Production of bioactive peptides by directed hydrolysis of protein rich wastes (developed by LEITAT) is an emergent technology. This method provides an innovative methodology based on turning the common process upside down, firstly predicting the enzymes activity according to a bioinformatics model and then validating the activity afterwards. The application at the moment is on the food and feed sector, by obtaining protein hydrolysates that can be used as feed additives. Nevertheless, potential application in the cosmetics or pharma sectors is foreseen. LEITAT exploitation intentions
are: offering the related know-how in collaborative projects with companies in the food and feed sector carrying out new studies in the field that can be profitable for the companies; exploring with companies the possible applications in other sectors; and replicate it in other areas, such as to apply it in other sub-products in order to expand the knowledge of LEITAT.

The Hydrolysis of protein rich wastes to improve digestibility (LEITAT) is a procedure that improves the digestibility of protein by products. The benefits of this technology are clear, it improves the digestibility without affecting the nutritive value of proteins. The main sectors of application are the feed and food sectors, Pulp and Paper (to improve the strength, stiffness and capacity of erase the paper or to remove fine particles from pulp), pharma and nutricosmetics. The technology can be interesting for all the main market players of the sectors stated before. LEITAT exploitation intentions are: offering the know-how related in collaborative projects with companies in the food and feed sector carrying out new studies in the field that can be profitable for the companies; exploring with companies the possible applications in other sectors; and replicate it in other areas, such as to apply it in other sub-products in order to expand the knowledge of LEITAT.

The Ultrasound and/or assisted protein extraction (LEITAT) is an enzyme and/or ultrasound assisted extraction methodology that allows the extraction of non-degraded protein and it has been designed and applied to the selected protein rich wastes of NOSHAN. There are some innovative aspects of LEITAT’s approach: the extraction technology is adapted to each waste and it is a non-aggressive process. The applications of this technology can be found in the food and feed sectors and in other sectors where maintaining bioactive levels is very important such as pharmaceutical and nutraceutical. The technology can be interesting especially for Food/feed players as the need of obtaining protein maintaining the highest bioactive properties is high. Pharmaceutical and nutraceutical players can be interested too. LEITAT exploitation intentions are: offering the know-how related in collaborative projects with companies in the food and feed sector carrying out new studies in the field that can be profitable for the companies; exploring with companies the possible applications in other sectors; and replicate it in other areas, such as to apply it in other sub-products in order to expand the knowledge of LEITAT.

The Tailored production of Pectin oligosaccharides (POS) by coupling of hydrolysis and separation (developed by VITO in collaboration with Università di Parma and Nutrition Sciences) aims to be flexible to the use of less-specific enzymes or enzyme cocktails, and to allow a more performant utilization of the pectin raw material used in the process and be able to produce more tailored pectic oligosaccharides having prebiotic properties. The benefits of the invention are clear because this new procedures could be implemented and have the potential to substitute the procedures currently used. This technology is quite specific and the main sectors of application of this technology are the feed and food sectors in order to valorize the wastes. Mainly, technology acquires focusing on the production, or improvement of feed or food additives can be found in the feed and food sector, respectively. The exploitation intentions of the involved partners are the following: NS could be interested in using the prebiotic for its own products production, meanwhile UNIPR can be interested in using the prebiotic products for further investigation, in this case, an agreement between the three parts should be reached that regulate the exploitation of the results.

Apart from each technology, NOSHAN can be transfered into the market as a whole process. To achieve this, the most suitable strategy is to transfer the invention licensing it to a third party, taking into account that the single technologies generated can be used and exploited by the partners interested.

To carry out the commercialization of the NOSHAN, all the partners will present the NOSHAN project and its results through their network after the end of the project in order to find any potential acquirer/opportunity to exploit it in the market.

Taking all this into consideration, we can conclude from one side that all the channels used to disseminate the projects have achieved the expected impact and that all the consortium has contributed to it. From the other side, the project has finished with six exploitable results that have a potential market within the feed, food and organic waste management sectors, there is an exploitable plan set for each technology individually and for NOSHAN as a whole and the partners involved are committed to continue their exploitation activities beyond the project.
List of Websites:
Project website: www.noshan.eu

Relevant contact details:
Scientific coordinator: Montse Jorba (mjorba@leitat.org)
Management coordinator: Raquel de Sousa (desousa@leitat.org)

LEITAT:
Raquel de Sousa - rdesousa@leitat.org
Montse Jorba - mjorba@leitat.org

VITO:
Kathy Elst - kathy.elst@vito.be

UNIPR:
Stefano Sforza - stefano.sforza@unipr.it

NS:
Geert Bruggeman - Geert.Bruuggeman@nutrition-sciences.com

IGV:
Janos Petrusan - Janos.Petrusan@igv-gmbh.de

EKODENGE:
Özge Yilmaz - ozge.yilmaz@ekodenge.com

KIM:
Elisenda Casanelles - ecasanelles@kimglobal.com

UCKERKAAS:
Jürgen Schöber - fermtecgmbh@gmx.de

VERTECH:
Erasmo Cadena - erasmo.cadena@vertech-group.com

ILVO:
Bart Van Droogenbroeck - Bart.vandroogenbroeck@ilvo.vlaanderen.be

PROVALOR:
Piet Nell - piet.nell@provalor.nl

AQON:
Marian Wilk - m.wilk@aqon-gmbh.com

Related information

Result In Brief
New technologies to valorise food waste and boost industry sustainability