New Advances in the integrated Management of food processing waste in India and Europe: use of Sustainable Technologies for the Exploitation of byproducts into new foods and feeds

Executive Summary:

The European and Indian fruit and cereal processing industries generate several million tons per year of by-products that are mainly disposed of through landfills and are thus largely unexploited sources of a number of valuable biobased compounds potentially profitable in the preparation of food ingredients and the formulation of novel food products with improved and healthy properties. The opportunity to design novel strategies to turn citrus and wheat processing by-products into food ingredients and food products via novel and sustainable processes was the main objective of the NAMASTE-EU project.

Novel improved methods and strategies for assessing the quality and the exploitation potential of citrus and wheat processing by-products have been developed and assessed. Microwave drying (MW) was selected among innovative technologies for the stabilisation of citrus by-products due to its effectiveness in maintaining microbiological safety while preserving the technological and/or sensory properties of the citrus ingredients obtained. As for wheat bran, optimal water activity for storage was determined as >65% relative humidity. Procedures were developed for obtaining valuable ingredients from stabilized citrus peels, such as citrus fibre, polyphenol extract and clouding agent, for the production of fermented wheat bran containing prebiotic oligosaccharides and probiotic lactic bacteria, and for obtaining oligosaccharides with high prebiotic index and ferulic acid as substrate for vanillin production via the combination of (thermal) pre-treatments and enzymatic digestion of wheat bran with different commercially available enzyme preparations.

The most promising ingredients were selected according to preliminary screenings for technological applications and combined for the
formulation of new food products, such as a citrus fibre-enriched fruit juice, a fruit-based beverage containing the clouding agent, snacks based on citrus fiber and citrus paste, a citrus powder-based monodose beverage, bakery products filled with HPH (High Pressure Homogenization)-treated citrus paste, citrus-based instant desserts and a bakery product based on pre-fermented wheat bran. All the developed products were characterized for their composition, technological, microbiological, functional and sensory characteristics. Moreover, the feasibility of the scale-up of the production of major ingredients from citrus by-products and wheat bran, and the interest of the industrial partners in the final applications, were adopted as the criteria for the selection of target final food products to be further tested for consumer acceptance.

The processes for the production of selected ingredients (High Pressure Homogenized citrus paste, citrus fibre and cloudy agent) and the selected food products prepared from them (i.e. refrigerated monodose beverage, citrus paste-based filler for bakery products and citrus filled snack) were assessed for food safety risk and environmental impact. Hazard analysis and critical control points (HACCP) studies demonstrated that the Namaste ingredients are safe raw materials to be used in different food processing technologies. According to LCA analysis, cloud production has the lowest level of environmental impact while the HPH paste has the highest one. Economic and market opportunities assessment were also performed through the full cost method and a web-based stakeholder consultation.

Overall, a systematic food chain approach for the valorization of citrus and wheat processing by-products into food ingredients/food products was established, consisting of the following steps: i) food chain flow scheme analysis, ii) chemical and biological composition analysis, iii) identification of potential application of by-products or extracted components, iv) identification of technological options for exploitation, v) practicability analysis, vi) selection of the strategies and technologies for valorization and vii) process and product development (also addressing food safety, sustainability, consumer acceptance and marketability issues). The food chain approach established might also be relevant to the valorization of similar plant-based by-products generated by the food processing industry. Cooperation between the EU and India Namaste projects was realized through the exchange of scientists, RTD protocols and results, as well as via joint dissemination activities, project meetings and the establishment and interaction with a European-Indian Industrial Platform.

Project Context and Objectives:
The European and Indian food industries generate many millions of tons (MT) per year of plant processing by-products, particularly in the fruit and cereal processing sectors. In the fruit sector, Europe is the third major citrus producing area in the world with approximately 10 MT. About 20% of European citrus fruit production goes for processing and more than 80% of this is for orange juice production. The residue resulting from its processing is mainly constituted by peels and pulp (pomace with seeds), for an overall amount of by-product generated corresponding to about 50-60% of the original mass processed, i.e. approximately 1 MT. A major part of the by-product is applied for cattle feed (often after drying) or disposed of as waste, while applications in the food domain include pectin, essential oils (D-limonene) and orange fibres. India, conversely, produces about one third of the global mango production (30 to 40 MT), between 0.5 and 1 MT of the Indian mangoes being processed annually with the generation of a solid side stream (peels and kernels) accounting for 40 to 60% of the original mass processed and a liquid waste (juice and wash water). Kernels are used to obtain mango kernel fat (mainly used for cosmetics), whereas dried peels are used for animal feeding or disposed of as waste. In the cereal sector, the European Union is, by far, the main world producer of wheat and accounts for over 20% of the production (about 10 MT/year), while Indian production of rice accounts approximately 20% of the 700 MT globally produced. The bulk of these grains are refined and used for food production, generating a wheat bran fraction accounting for up to 25-30% w/w of grain and a rice bran fraction accounting for approximately 6% w/w of grain, which are currently used predominantly as animal feed or disposed of as waste.

The current valorization of these by-products is thus very limited (e.g. use in animal feed and composting); as a result, a large portion of these materials are disposed of in landfill, which itself is becoming increasingly restricted (e.g. EU Land-fill Directive and related international legislation) in order to reduce pollution and health hazards.

Nevertheless, prior to disposal, such food processing by-products can be considered sources of valuable food ingredients to be exploited in the production of new food products and feeds. Indeed, after specific pretreatments with physical and biological agents followed by tailored recovery procedures, they might provide specific natural antioxidants, antimicrobial agents, vitamins, etc., along with macromolecules (e.g. soluble fibres), bioactive oligosaccharides, oligopeptides, and pigments. Further, some of the compounds occurring in the hydrolyzates resulting from the by-products pretreatment can be transformed into more sophisticated molecules like flavors and fermentation products throughout tailored biotechnological processes. For instance, citrus peels possess a large variety of bioactive compounds that might be considered as potential sources of functional components, such as phenolic acids, flavonoids - e.g. hesperidin, narirutin, naringin and eriocitrin - limonoids and fibres. Citrus fibres are being also considered of higher quality than those from cereal due to a better balance of soluble and insoluble dietary fibre (DF) content, to their content of bioactive compounds (flavonoids and vitamin C) with antioxidant properties, and also for their functional and technological properties. Wheat bran can be used to enrich breads and breakfast cereals in fibre content, but less emphasis has been given to enhancing fibre quality in foods through modification to the fibre matrix and the control of its physicochemical properties. Deconstruction of these by-products into their
polymeric, oligomeric and individual components, through mechanical and/or (bio)chemical means, could provide valuable streams for exploitation in a number of different applications in the food industry. The DF content of cereal bran is based mainly on their pentosan content, mainly as arabinoxylans and xylans. The presence of phenolic acids, in particular ferulic acid, esterified to arabinoxylans gives this fraction the potential to be exploited as a source of polymers and oligosaccharides with anti-oxidant and/or prebiotic properties for food use and also a potential substrate for biotechnological production of vanillin.

The exploitation of these by-product streams is often compromised by their inadequate biological stability (i.e. their propensity for microbiological spoilage and oxidation, as well as for proliferation of pathogenic agents). In addition, despite several studies have been made to recover valuable compounds from food by-products, an important still open challenge is the development of products that meet the consumers' high quality standards for safety and organoleptic characteristics. Furthermore, a crucial step in the conversion of food by-products into potential new ingredients and food products is adopting technological processes that allow the production of microbiologically and chemically stable ingredients/products while minimizing bio-active, nutritional and functional properties losses.

The development of technologically and economically viable approaches to convert fruit and cereals processing by-products into appropriate ingredients and the development of new, high value food products and feeds would allow to reduce the volume of by-products disposed of and the production of higher-value foodstuffs. This would also contribute to close the circle within large fruit and cereal food industries and/or to create new synergies between fruit/cereal processing industries and food producing industries, with remarkable positive effects on the sustainability and the economic competitiveness of the European food industries.

In this context, NAMASTE EU had the technical objective to develop and assess laboratory-scale experimental protocols relying on economical and environmental sustainable processes and technologies for converting citrus and wheat processing by-products into new food ingredients and food products with improved and healthy properties. It also had the strategic objective to integrate its RTD efforts in a EU-Indian trans-national scenario to produce common, industrially driven, innovative protocols and sustainable processes for exploiting fruit and cereal processing by-products of major relevance for the two continents into new food products and a feed for aquaculture with new market potential. The by-products and waste selected by the two twin NAMASTE consortia, e.g. wheat bran and citrus by-products in EU and rice bran and mango and pomegranate by-products in India, share common and complementary features, such as: a) a poor valorisation and extensive disposal in landfill with relevant environmental problems, b) large availability at low costs, c) similar biochemical composition rich in healthy molecules, all this favoring a synergic and effective RTD cooperation between the two consortia.

To reach these two main goals, the following specific RTD and innovation objectives were identified by the NAMASTE EU consortium:

- development and assessment of novel protocols for the selection, integrated characterization and stabilization of citrus and wheat processing by-products (WP2);
- build up and assessment of physical/chemical and biological procedures for obtaining food ingredients, such as antioxidants, antimicrobial agents, dietary fibres (DF), prebiotic oligosaccharides, etc., from the stabilized by-products, and for the biotechnological production of natural vanillin from bran hydrolyzates (WP3);
- build up and assessment of practices (protocols and technologies) for exploiting natural ingredients and pretreated by-products in the formulation of new food products of interest for the EU-Indian food markets and a new feed, as well as of procedures for the assessment of the quality, chemical and microbial safety of developed new food products and feed and the environmental and economical sustainability of the processes employed (WP4);
- development of strategies for the analysis of risks, economical benefits and new market opportunities for the new food products/feeds and selected technologies (WP5);
- promotion of joint training of young scientists and exchange of protocols within and between the two NAMASTE consortia and setting up of a EU-Indian Industrial Platform composed by large food industries and SMEs as validation players committed to provide feedbacks to the consortia (WP6).

Project Results:

WP2 - Characterization and stabilization of by-products from EU industries

The two co-product classes of interest for NAMASTE-EU are wheat bran and citrus peels (Figure 1). Whilst wheat bran has low moisture content citrus peels are highly hydrated. This affects the strategy for co-product stabilization. Currently the major use of citrus by-products is limited to cattle feeding, with up to a 24 %, used for biofuel production. Similarly bran, and in particular wheat bran, is currently used for the production of low-value products, like composts and livestock feed, and significant amounts are disposed in landfills as waste.

Both citrus peel and wheat bran are a potentially rich of ingredients of interest to the food processing industry. A crucial step in the conversion of food by-products into potential new ingredients and foods is adopting technological processes to produce microbiologically and chemically stable ingredients/products whilst minimizing losses of bio-active, nutritional and functional properties.
The objectives of the first part of the project were the characterization of the raw materials and the definition of suitable pre-treatments for their stabilization, prior to further downstream processing. Fibres from citrus are currently considered of higher quality than those from cereal due to a better balance of soluble and insoluble dietary fibre (DF) content and, also, due to their higher water and oil retention capacities. The additional advantage of citrus DF is their content of associated bioactive compounds (flavonoids and vitamin C) with antioxidant properties, which may have health promoting effects better than DF.

Bran is particularly rich in DF and contains significant quantities of starch, protein, vitamins, and minerals. The presence of phenolic acids, in particular ferulic acid, esterified to arabinoxylans gives this fraction the potential to be exploited as a source of polymers and oligosaccharides with anti-oxidant properties for food use and also a potential substrate for the biotechnological production of vanillin. The first phase of the project was dedicated to identifying and quantifying target value-added compounds (eventually new ingredients) of citrus and wheat processing by-products and to identify constraints on proposed innovative valorization pathways. Extensive published data related to the European production and main physico-chemical and microbiological properties of citrus by-products and wheat bran (EU) were also collected and analysed.

Citrus by-products, collected from various processing companies in Spain, were analyzed for centesimal composition. Citrus polyphenols (TPC) were extracted from peels of six samples of different varieties of orange (Citrus sinensis) and production sites and from lemon (Citrus limon var. fino and verna) and mandarin (Citrus reticulata var. clementina). Results are similar to those previously reported in the literature. No relationships were observed between phenol content and the variety or production site of the orange, indicating that variability in TPC was due to different degrees of ripeness. All samples were within food-grade microbiological quality for further processing.

Wheat bran can also be considered of food-grade standard, although with a relatively high associated microflora. A survey on the production statistics of wheat bran has shown that geographical origin and wheat type (e.g. hard/soft) have little effect on the composition of the bran.

The second phase of WP2 concerned the microbiological safety and stability of by-product raw materials. In general, stabilization involves either maintaining a low water activity, i.e. low relative humidity, or heat treatments sufficient to sterilize a product, but avoiding chemical and physical damage to target compounds. Whilst wheat bran has low moisture content citrus peels are highly hydrated. This affects the strategy for by-product stabilization. Drying costs are critical, especially for high water content material, as in the case of citrus by-products. Different innovative drying technologies were assayed for citrus by-products.

Stabilization experiments with wheat bran involved freeze drying and air drying at different temperatures and microbial stability was monitored during storage under controlled relative humidity. Optimal water activity for storage has been determined as >65% relative humidity, while some critical control points have been identified relevant for preservation before enzymatic treatments, extraction of polysaccharides or bioconversion of bran compounds into desired ingredients. These bioconversions are associated with an initial high temperature treatment, as part of DF preparation, which preserves the microbiological safety of bran ingredients.

Protocols for the pretreatment of citrus by-products, e.g. citrus peels, to prevent microbiological spoilage have similarly been defined. Additionally, there was the need to minimize the enzymatic degradation and loss of compounds of interest, like polyphenols. Innovative technologies like microwave drying (MW) or combined conventional drying with thermo-mechanical procedures were assayed as alternative to conventional drying methods. Such methods use low temperatures to stabilize the material prior to further processing to obtain citrus peel extracts and DF. MW drying also involves shorter processing time and achieved a higher product quality, did not affect the phenolic content and favored phenolics release during extraction. Instant Controlled Pressure Drop (DIC) technology, a combined thermo-mechanical treatment, facilitates drying through the expansion/structural change also improved extraction processes. Drying temperature is critical for the content of polyphenols and on the physico-chemical properties of the DF. Blanching technologies to inactivate enzymes before drying also improve ingredient quality. Both MW and DIC modify citrus microstructure and this improved the technological properties of the DF and seems also to favor the further extraction of phenolic compounds. All methods adopted for citrus pomace stabilisation use low temperatures. The criterion for comparing procedures was based on sensory properties, e.g. colour, drying but also considered operational costs. MW does not display notable adverse effects on either technological or sensory properties of the citrus ingredients and is relatively low cost. MW technology was also selected as the preferred drying method for stabilizing citrus peels since it was effective in maintaining microbiological safety.

WP3 - Natural ingredients for new foods: pre-treatment of by-products and waste and recovery and production of natural molecules

In WP3 the major objectives were to characterize ingredients obtained from wheat bran and citrus pomace in terms of composition, bioactive properties and technological functionality. The aim was to develop and optimize innovative green biotechnological processes for the production of citrus fibres, gelling agents and cloud agents from citrus pomace and bioactive fibre concentrates, prebiotic oligosaccharides and vanillin from wheat bran.
Wheat Bran

Wheat bran is a by-product of the flour milling industry and comprises mainly the pericarp and aleurone layers of the wheat grain. Wheat bran is used as an ingredient in foods intended for human consumption in its own right.

The scope for protocol development to exploit wheat bran was to develop a range of hybrid processes at the laboratory scale to convert and recover one or more of the following products:
- Oligosaccharides with potential prebiotic activity from component arabinoxylans (AX)
- A bran product pre-fermented with carbohydrases and including probiotic agents
- Ferulic acid for bioconversion to bio-vanillin
- Enzyme-recalcitrant wheat bran fibre residues
- A peptide- / maltose-rich product suitable a growth / feed medium

The objective was to develop environmentally friendly protocols for an holistic bioconversion of wheat bran for added value, based on the combination of (thermal) pre-treatments and enzymatic digestion with different commercially available enzyme preparations. Figure 2 shows the general protocol for bran treatment.

Figure 3 illustrates the change from particulate bran to fibre concentrate (~50% of the untreated bran) to preparation of powdery oligosaccharides (~20% of the fibre concentrate).

The non-starch polysaccharide (NSP) content of the wheat bran (bulk) was around 40%, typical of wheat bran and composed mainly of arabinose (ara), xylose (xyl) and glucose (glc). Phenolic acid present (~0.08%) was mainly ferulic acid (~70% total), the substrate for bio-vanillin production. Milling fractions vary in content of NSP and in the relative proportions of component sugars (Figure 4), thereby allowing selection of fractions with features which may be important for bioactivity.

Different fractions of bran recovered from the flour milling stream give a range of oligosaccharide yield (degree of polymerisation [DP] >10), typically 60 - 80% of the sample weight. The ratio of arabinose:xylose (mean 32±0.06) indicates the oligosaccharides are apparently less branched overall than in arabinoxylans from the milling fractions (mean 0.62±0.06). This infers that the oligosaccharides are derived mainly from aleurone tissue, which could be significant in selecting substrates suitable for production of high yield and/or high bioactivity oligosaccharides. For example, although fraction 4MD/B2 (Figure 5) shows a high prebiotic index (PI) and yield from the fibre concentrate, the yield from the original bran fraction is low, whereas fraction BK gives a similar PI and higher yield from the original milling fraction. Thus, fractions of bran recovered through flour milling offers the opportunity to select oligosaccharides with a PI to rival that of fructo-oligosaccharides (FOS). Batch culture and FISH analysis have confirmed the relative PI of the milling fractions.

The treatment of bran with enzymes, e.g. Driselase, to prepare a fermented fibre product is also likely to generate oligosaccharides, though concentration will be low and DP may differ from that found by direct extraction of oligosaccharides. However, the fermented bran product does support proliferation of the probiotic organisms L. casei and L. sakei and they survive dehydration. This demonstrates an alternative mechanism for developing ingredients which can enhance the delivery of prebiotic/probiotic agents in foods.

Screening for technological applications (Table 1) demonstrated that the oligosaccharides are acceptable in bakery and in some dairy products and can improve dough properties.

The total antioxidant capacity (TAC) of bran is variable between the milling fractions (Figure 6) and derives mainly from water soluble components. However, some fractions, e.g. CBF, can have a significant ethanol soluble TAC. Treatment of bran with enzyme cocktails to produce the pre-fermented bran (Figure 7) shows some enzyme treatments, e.g. Driselase, can enhance TAC; presumed to be through selective solubilisation of bound components. The presence of Lactobacilli does not affect TAC and their proliferation increases from ~107 CFU/g to ~109 CFU/g. Hence, a useful vector for probiotics can be developed through pre-fermented bran, but TAC does not appear to influence probiotic proliferation.

Similarly, wheat bran is potentially a good source of bio-vanillin, produced through bioconversion of ferulic acid. Modification of the protocol for bran fibre preparation and digestion gives a limited release of ferulic acid, corresponding to about 15% of the ferulic acid present in bran. Although aleurone tissue, the major source of ferulic acid in bran, is disrupted by xylanase treatment, the need for a more severe physical treatment has been identified to improve the esterase activity required for ferulic acid release.

Optimal conditions for biomass growth and storage, bioconversion of food-grade ferulic acid have been defined and an innovation has
been to use a recombinant Pseudomonas fluorescens strain to produce vanillin. These conditions achieve vanillin concentrations ~8.4 mmol/L, the highest so far reported literature value. In addition, flexibility built in the protocol developed allows selection between higher product concentration and higher productivity; relying on the same high yield and selectivity, by changing the initial substrate concentration.

The protocol developed for bioconversion allows ferulic acid in purified wheat bran hydrolysate to be bio-converted to vanillin with the same efficiency as food-grade ferulic acid (Figure 8). The molar yield of 55.1% and selectivity 68% compares well to the 63.2% molar yield and 71% selectivity obtained with pure, food-grade ferulic acid and is greatly increased from the ~21% molar yield and ~28% selectivity which had been achieved before purification of ferulic acid in bran hydrolysates through removal of reducing sugars. This is related to removing the carbon sources available for microbial growth and associated to enzyme activities responsible for vanillin oxidation.

Citrus pomace
Citrus pomace is a by-product of juice extraction from the citrus fruits and has two principle components: whole peel (rind) and ‘rag’. The rind is principally the flavedo (pigmented outer layer) or epicarp and the albedo (interior, whitish spongy material) or mesocarp, whilst ‘rag’ is the residue left behind after juice extraction and comprises cores, segment walls or membranes, juice vesicles and seeds.

The scope for protocol development to exploit citrus pomace (orange and lemon) was to provide processes at the laboratory scale to produce:
- functional dietary fibres;
- polyphenols and carotenoids;
- clouding agent.

The objective was to develop processes to obtain citrus peel extracts and a fibre fraction as intermediate products or ingredients with a defined functionality (technological or physiological) that offers added value to citrus pomace. Figure 9 outlines the protocol for citrus pomace treatment.

Innovative process technologies, involving MW drying for product stabilization and DIC for product expansion were used to obtain dietary fibre. Each yields a high quality dietary fibre with improved functional properties. MW reduces drying time threefold compared to conventional drying method, an advantage when considering microbial spoilage and product quality. In addition, the expansion effect of DIC may improve water binding capacity in foods. An ingredient which assayed at over 74% dietary fibre and with high water retention capacity was derived from citrus pomace, which compares favourably with existing products. For commercial exploitation improved sensory properties remains a requirement. Figure 10 shows the citrus fibre preparation, compared to an existing commercial citrus fibre source.

To eliminate bitter molecules, flavours and colour from fibre following MW drying, classic Solvent Extraction (SE) and Ultrasound Assisted Extraction (USE) were compared. USE is preferred for reproducibility, processing time, solvent consumption and temperature.

For sequential extraction of polyphenols and carotenoids by supercritical CO2, solvent requirement limits its practical application. A co-product of the debittering step is a polyphenol rich extract, with a polyphenol content of 120 g gallic acid equivalents (GAE)/kg and a carotenoid content of 1.4 g carotenoid equivalents/kg extract. These results compare favourably with published values for polyphenols. The flavonoids naringin (11 h/kg) and hesperidin (31 g/kg) were the major polyphenols present and are flavonones found almost exclusively in citrus. Quercetin-8-glucoside, rutin, p-coumaric acid, ferulic acid and caffeic acid were also detected, but at low concentrations. The protocol developed allows co-extraction of a crude polyphenol rich extract and a citrus fibre preparation. Each can be further developed for use as ingredients in the formulation of food products and feed with technological and health properties.

However, modifications to improve one property, e.g. introducing acid extraction to improve fibre gelling, can detract from extraction of other ingredients, e.g. polyphenol loss. The cloud prepared from citrus fibre was less turbid when compared with commercial products (Figure 11). However, stability was comparable with commercial products. In beverages, cloud had to be added at a concentration fourfold to that of commercial clouds, but it was more stable than a reference orange cloud. The debittering through resins also resulted in a significant decrease in turbidity and the limonin content of the non-debittered cloud was very low. The need to expand the use of higher doses of cloud and to take account of the degree of ripeness of the oranges was identified.

The protocols developed have demonstrated that dietary fibre extracts with defined functional properties which can rival existing products can be produced from citrus pomace and thereby provide a viable exploitation route for citrus pomace. The extracts are available with bittering agents and colour removed and the components removed can also be exploited as commercial ingredients.

Screening for technological applications (Table 2) demonstrated that the citrus fibres were suitable mainly for use in savoury products, as a fat replacer and to enrich in fibre. Sensory screening as a thickening agent, where gelling properties are important, was not successful (e.g. dressings, meat products).

A practical method was developed within Namaste for the ethical assessment and on-site food safety audits of ingredients produced in non-food grade premises (Section 4.1.4: ‘potential impacts’). This established that food samples incorporating the test ingredients
represented no increased risk for the sensory evaluators compared to similar retail foods.

WP4 - New foods and feed formulation and production

The main overall objective of the WP4 was to design and develop at laboratory scale new food products and a feed based on wheat bran and citrus by-products or natural compounds derived from their co-products produced in WP3, by using different (bio)technological approaches. All the developed products were characterized for their composition, technological, microbiological, functional and sensory characteristics. Moreover, the feasibility of the scale-up production for obtaining ingredients from citrus by-products and wheat bran, and the interest of the industrial partners in the final applications were used as the determinant criteria for the selection of target final food products to be produced for consumer acceptance tests.

Fruit juices and/or beverages based on citrus-derived ingredients

The natural extracts obtained in WP3 from citrus peels were used in the production of fruit juices or fruit juice-based beverages. The product prototypes developed were three: an orange juice enriched with citrus fibre, a polyphenol-rich fruit juice-based beverage, and a soft drink with the clouding agent obtained from orange peels (Figure 12). All the prototypes were tested by trained panellists and compared with benchmark commercial products.

According to the study, the non-debittered clouding agent was adequate for testing in an orange juice-based beverage. Moreover, the addition of the debittered citrus fibre to conventional orange nectar resulted in a potential quality product in terms of both visual appearance and taste as compared to benchmark products (Figure 13).

Two prototypes were finally selected, produced at pilot scale and sent to Hungary (CCH) for a consumer's acceptance test: a citrus fibre enriched fruit juice and fruit based beverage using clouding agent.

Preparation of new food products

By using the ingredients produced and characterised in WP3 or crude material obtained from the citrus material after appropriate pre-treatments including also the selective extraction/removal of undesirable compounds or stabilization by dehydration, the following food products were formulated and prepared at lab-scale level (Figure 14):

1) several snacks from citrus by-products
2) a citrus-based monodose beverage
3) two citrus paste-based filled bakery products
4) a bakery product based on pre-fermented wheat bran
5) two citrus-based instant desserts

Several pre-treatment and operation conditions were evaluated in order to stabilize the raw materials prior to their processing. In particular, to choose the orange-ingredient form, various trials were done to avoid citrus by-product colour and bitterness. Extraction of coloured and bitter compounds was tried by means of solvent extraction, basic treatments, acid treatments and supercritical fluids technologies. Also limonin encapsulation was tested to avoid bitterness. High hydrostatic pressure (HHP) treatments of orange paste were used to evaluate its effect on bitterness, but also on its texture and mouthfeel properties.

Concerning debittering of citrus fibre, limonin removal resulted to be more effective when the raw material was wet blanched, thus achieving a product with limonin levels below the threshold of perception, although most polyphenols and carotenoids were lost. HHP treatments reduced the content in bitter compounds, but not enough to be perceived in sensory tests. However, some positive changes in the textural properties of the citrus paste were observed due to HHP treatment. More precisely an increase in the firmness, consistency, cohesiveness and viscosity index of the paste was detected. Finally, the strategy used to obtain sensory acceptable products was based on masking the bitter taste by modifications in the formulation of the products.

As far as the citrus-based beverage and filler, a preliminary treatment for the stabilization of the citrus by-products was set up in order to obtain a citrus powder that was used for the formulations of both products. Concerning the beverage, the main technological problem that was taken into consideration was the identification of the conditions preventing the growth of spoilage microorganisms (mainly yeasts such as Saccharomycyes cerevisiae) while assuring good sensory and quality properties. This aspect was successfully faced by combining reduced Aw values (> 0.96) with a mild heat treatment (1-3 minutes at 70°C) which resulted in a product with a shelf-life up to 55 days. Moreover, the addition of sugar to reduce the Aw also allowed to mask the bitter taste which characterize citrus by-products and limit their use if any debittering pre-treatment is performed.

For the stabilization of the citrus-based filler for the bakery products, High Pressure Homogenization (HPH) was used as a processing technology alternative to heat treatments. HPH treatments with pressures up to 150 MPa was able to stabilize the citrus-based formulations preventing the growth over storage of the spoilage yeasts. In fact, no growth up to 6 Log CFU/ml, which is considered a threshold level for yeast spoilage in fruits, was detected up to 52 days of refrigerated storage. Similarly to HHP, also HPH induced significant changes in the microstructure of the citrus-based formulations and their texture. In particular modifications in the viscosity
and in the consistency of the citrus (Figure 15) were observed thus making the treated products suitable to be used as a filler for: 1) a sweet product made of two soft bakery layers filled with the HPH-citrus; 2) crunchy biscuits containing bran, citrus as filler and covered by chocolate. Both the products did not show any evident modification in the texture, colour and consistency over a 1 month storage at room temperature, provided that contact with high humidity is avoided.

For the bakery product, the possibility to use the bran pre-fermented by selected lactic acid bacteria as an ingredient for bread making was evaluated by the analysis of the technological, textural and sensory characteristics of breads produced by bakery yeast and sourdough fermentation. It was defined that levels of 5% are not adequate for the production of breads enriched with wheat bran; to produce breads with acceptable sensory and textural properties, levels up to 16% should be used. Moreover, while the addition of raw bran caused a significant reduction of the dough development, volume increases similar to the control samples (i.e. with no bran added) were observed when pre-fermented bran was used. Furthermore the addition of the pre-fermented bran showed to improve the functional properties of the breads such as its scavenging activity (Figure 16), particularly when sourdough fermentation was used.

Evaluation of the possible use of the new food products within a balanced human diet

In order to evaluate the contribution of the wheat bran and citrus derived ingredients produced in WP3 to dietary recommendation when used as ingredients for the new food products (produced in WP4), their main nutrient and “non nutrient” components, bioactive compounds contributing to functional activities, such as the antioxidant or prebiotic ones, were assessed also taking into consideration how the process conditions and technologies adopted for their production can affect their nutritional value. Moreover, possible risks for the consumers related to the presence of pathogenic and/or toxigenic microorganisms, allergens, heavy metals and pesticides in the bran and citrus derived ingredients are taken into consideration.

The critical analysis of the information collected evidenced that no microbiological risk is associated to citrus and wheat bran derived products. Although grain directly entering the food chain may carry an endogenous microbial population, it is considered within acceptable levels for food safety if stored under conditions appropriate to prevent microbial proliferation, i.e. relative humidity >65% and temperature 10-12°C. Moreover, the technological processes and conditions used to obtain oligosaccharides, and wheat bran fermentation by lactic acid bacteria as well, minimise their survival and/or proliferation. As far as the pesticides, special attention should be paid to citrus fruits treated with the fungicides post harvesting due to their long persistence in the fruit; however, the analysis of the pesticides considered environmental contaminants and of PCBs demonstrated that they were found under the detection limits. Also for raw bran, heavy metals resulted to be within the stringent EU food safety regulations (>200 µg/kg bran for Cd, >200 µg/kg cereal fresh weight for Pb and 100 µg/kg for Hg). Moreover, such a risk may be further reduced by the pre-treatment steps used to stabilize the raw material prior to its use.

In order to prevent possible nutritional losses due to processing, special attention must be paid to the processing conditions adopted, and the mildest temperature/chemical conditions should be used when possible to preserve bioactive molecules, e.g. the polyphenolic compounds and their antioxidant activity, or technologically important compounds, e.g. soluble fibres and their water retention capacity. In fact, from a chemical point of view it is well known that both whole grains and fruit processing by-products represents a potentially valuable resource that can be developed into high value products. Particularly, citrus peels and their extracts have been reported to have potent health and preventive activities due to the abundance of flavonoids, while whole grains are rich in fibre and antioxidants, including trace minerals and phenolic compounds, which have been linked to disease prevention.

In order to assess the possible contribution of two NAMASTE ingredients, i.e. wheat bran and citrus fibre, to the nutritional characteristics of conventional foods, a NAMASTE bread and a NAMASTE beverage were evaluated as examples. In particular their contribution to the fibre content and total antioxidant activity (TAC) of the newly formulated food products was evaluated showing that the use of the NAMASTE bran can enhance the fibre content and total antioxidant capacity of the newly formulated bread. In particular, the fibre content increase in the NAMASTE bread varied from 2.6 to 11.42 g/100 g of baked bread depending on the bran fraction used (Figure 17), while the theoretical TAC increase was more than 350 µmol trolox equivalents (T.E.)/100 g (Figure 18). On the other hand the NAMASTE beverage contributes to the intake of dietary fibre if compared to conventional orange and citrus juices which do not contain any fibre.

On the basis of these data and considering the Recommended Dietary Allowances (RDA) for fibres (25 g/day in adults), the use of NAMASTE ingredients can improve their nutritional characteristics of the final products with the wheat bran contributing to recommended fibres intake for 10.4 - 45.68 %. Similarly, the NAMASTE beverage contribution to the optimal fibres intake is near 8%, while the contribution of the same amount of conventional citrus beverage is 0%.

According to EC regulation on nutrition and health claims made on foods, the NAMASTE bread would be allowed to use the claim “rich of fibre” regardless the type of NAMASTE bran used for the enrichment, while the NAMASTE beverage should be allowed to use the claim “source of fibre”. Moreover, the NAMASTE bread could bear the following health claims:

- High in wheat fibre. Wheat bran fibre contributes to an acceleration of intestinal transit (the effect is obtained with a daily intake of at least 10 g of wheat bran fibre);
- High in wheat fibre. Wheat bran fibre contributes to an increase in fecal bulk.

Consumer acceptance of the produced new food products
In order to understand consumer acceptance of ingredients and food products developed in the NAMASTE project, different consumers tests were carried out. As some of the products could not be tested with large number of consumers, the acceptance of the different product concepts was assessed by an using an online survey. Such a survey aimed to present the product ideas, the novel attributes and advantages of the products and to provide support in selecting the potentially successful samples. Three product types were then selected from the proposed NAMASTE product concepts to test them in tasting sessions with 100 Hungarian consumers. Moreover these samples were tested also with trained sensory panel as well.

The online survey was based on a questionnaire consisting of three parts. A first part with the description of the products developed in the NAMASTE project. The participants evaluated their preferences, buying intent and consumption frequency of each product type. The second part of the questionnaire explored consumers’ attitudes towards sustainability and use of by-products. The third part contained buying intent regarding the NAMASTE products with the information shown about the by-product based ingredients.

The NAMASTE products selected for the survey were:

- Snack bar
- Citrus paste biscuits
- Yoghurt dessert with HPH citrus paste
- Fibre enriched cake based on pre-fermented whole and concentrated wheat bran fibre and citrus paste
- Instant citrus dessert

The online study showed that all the proposed product ideas/concepts recorded good consumer acceptance. Especially the fibre enriched cake filled with citrus paste recorded high liking levels. On the other hand the consumers found the product concepts of the yoghurt with citrus paste, the citrus cake biscuits, the snack bar and the citrus instant dessert as being acceptable. Moreover, all the products were perceived as being healthy based on their description and would be bought by consumers, particularly the fibre enriched cake and the citrus paste biscuits. The purchasing decisions of the respondents were mainly influenced by flavour, best before date and price.

Concerning the consumers’ attitudes towards sustainability, most of them found favourable the use of advanced food technologies to produce ingredients from citrus peels coming from the juice production in order to reduce load on environment, to improve the nutrition profile and sensory characteristics of the products.

A consumer’s acceptance test (n=100) was performed on the following products that were prepared in enough quantity and food grade by using the NAMASTE ingredients produced in WP3:

- orange drink samples, one prepared with NAMASTE cloud and the other prepared with a commercially available benchmark cloud;
- orange juices, one containing NAMASTE fibre and a commercial one;
- bakery product filled with NAMASTE citrus paste.

The consumers tasted the products and evaluated their appearance, aroma, flavour and texture. In addition they were asked to indicate how much they liked the product and how likely it was that they would buy this product.

Results revealed that the orange drinks and juices products prepared with the NAMASTE ingredients received moderately high liking scores. In particular the orange juice based beverage with the non-debittered version of cloud was accepted and qualified as similar to the benchmark sample. Moreover, almost half of the participants indicated that they would buy the product prepared with the NAMASTE cloud. The NAMASTE citrus paste filled bakery products recorded moderately high liking levels. In particular the participants liked the appearance of the product, but they gave lower preference scores for texture. Moreover, the result of the sensory evaluation with trained assessors showed that the NAMASTE drinks had moderate orange flavour, but balanced sweet and sour taste and the NAMASTE citrus paste had weak orange aroma and flavour with mild acidic and sweet taste.

Scale up technical feasibility of selected processes

As part of the work done for the characterization and assessment of new food products and food processing, a study and assessment from the technical point of view of the feasibility of defined processes for their scale up to industrial processing was also performed. In particular the following processes, developed within the NAMASTE project at laboratory scale, were evaluated:

- the processes of the citrus fibre, debittered citrus fibre and polyphenol extract products;
- the processes of the citrus cloud product;
- the processes of oligosaccharides and fibre concentrated bran.

On the basis of the information (flow charts, technologies and process parameters, yields, raw materials quantity of a processing plant, expected market size) collected for the laboratory work, the draft flow charts on industry scale were drawn and the capacities for the draft industry scale productions which needed to meet the demand of the potential market were estimated. Taking into consideration that an industry scale technology should be able to adapt to the changing conditions on the market, flexible solutions, to which the capacities can be adapted on the future in relatively easy way when the market size demand become already more concrete, were drawn up.

For the processes involving citrus by-products, an estimated hourly capacity of citrus peel ~8500kg/hour (i.e. 130 working days, 16
The requirements of the by-products for valorisation have been described from the quality, safety and risk point of view. Storage,

Food safety risk assessment for selected valorisation of by-products

products that fulfilled the mentioned conditions are found to be three: High Pressure Homogenized of citrus peel, citrus peel and cloudy agent. The sufficient quantity of products in previous steps to perform a consumer test, the food-grade certification of the processing equipment to processes to produce foods. The criteria to select the products to be assessed in WP5 were among other: the possibility to obtain

In NAMASTE the “cradle to cradle” concept has been applied and by-products have been considered as raw materials in the new processes to produce foods. The criteria to select the products to be assessed in WP5 were among other: the possibility to obtain sufficient quantity of products in previous steps to perform a consumer test, the food-grade certification of the processing equipment to produce new foods, the exploitability and real possibilities in the market and the time constrain within the NAMASTE project. The products that fulfil the mentioned conditions are found to be three: High Pressure Homogenized of citrus fibre, citrus fibre and cloudy agent. In Table 3 a summary of the discussion and selection of the NAMASTE products for WP5 is presented.

Food safety risk assessment for selected valorisation of by-products

The requirements of the by-products for valorisation have been described from the quality, safety and risk point of view. Storage,
transport and handling conditions have been defined for optimal valorisation. All the aspects relevant for selected processing industries waste have been considered, with special focus on factors of potential microbiological and chemical related health risks (pesticides, heavy metals, pathogens, mycotoxins, aflatoxins, etc.). The hygienic and safety aspects have been approached with the HACCP methodology.

Most of the potential toxicological issues to be considered in the case of the citrus fibre, clouding agent and HPH paste reflect either concentration effects or the use of non-permitted compounds. The risk of the presence of non-permitted compounds is considered to be low since the fruit is sourced from Member States. At existing manufacturing operations, where the contamination status of the raw material is known and evidences are available that the level of contamination is low the usual GAP based practices can be applied. The HACCP studies were made by anticipating that the by-product valorisation will be carried out by a specialist company or a separate business unit not by the fruit juice manufacturing company itself. The decision whether a fruit processor will carry out of the valorisation of its own by-products or it will be made by a specialised company is significantly influenced by the size of the operation of the business. The low pH value of the peel provides reliable control for prevention of the growth of pathogens at pH ≤ 3.8. For the moulds and other spoilage organisms chilled storage at ≤ 4 °C up to maximum 24 hours is recommended. Practical experience shows that below 4 °C the formation of mycotoxins is not likely within 48 hours. Even if the low temperature is not necessary it prevents the toxin formation by some moulds. The processes assessed for HACCP were the production of citrus fibre, production of debittered citrus fibre, production of debittered citrus clouding agent, citrus paste by HPH of citrus fibre, citrus paste and debittered citrus paste by enzymatic method, processing of citrus extract.

The HACCP study of some demonstration products prepared using selected ingredients was carried out to assess whether additional food safety aspects affecting the production of the ingredients have to be considered. The final products assessed were, the processing of refrigerated mono-dose product, the processing of the shelf stable filler for bakery, the processing of fruit enriched breakfast cereal and the processing of citrus filled snack.

Summarizing the hazard analysis of citrus fibre, the citrus clouding agent, the HPH citrus paste and their proposed processes for their production it could be established that the Namaste ingredients after controlled processes can be used as safe raw materials in different food processing technologies keeping the determined process parameters.

Environmental analysis

Environmental aspects have been assessed with the Life Cycle Assessment methodology (LCA), a technique to assess environmental impacts associated to all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and final disposal. Within the WP5 the three selected process environmental impacts were compared to the current use of orange peels (cattle feeding and landfill). In order to perform the LCAs to the different processes the some technical details were defined.

The functional unit is defined as “the treatment and processing of one ton of orange by products generated in an orange juice production company in Spain” in this work.

The system boundaries determine the unit processes to be included in the LCA study. For citrus fibre production from orange peels 5 main steps were considered: blanching, separation, drying and extraction with alcohol and a final drying and milling. The auxiliary process is alcohol distillation to recover a secondary product, a polyphenolic rich extract, and the alcohol for its reuse. For the production of clouding agent from orange peels 5 main steps were considered: blanching, wastes separation, enzymatic processes, second separation and final concentration of the cloudy agent product. And finally for HPH citrus paste from orange peels 3 main steps were considered: freezing, milling and HPH treatment.

The assumptions and limitations. The new products are produced close to the orange juice company assuming there is no transportation of raw material. Moreover the orange peel by-products do not account for any environmental impact due to the fact of being a “waste” of other process. The avoided products have not been taken into account (e.g. production of fibre) and none of the possible reuse of process by-products has been considered.

The allocation method is the environmental load of a process when several products share the same process and it is defined by partitioning the input and the output flows of a process to the product system under study. In the studies the LCA of the process was assessed, therefore no allocation has been defined and the impact is evaluated for the same quantity of raw material or main product produced.

Impact categories selected. The Hierarchist version of the ReCiPe midpoint method has been selected. The 18 impacts were evaluated, but the following were considered: Climate change, terrestrial acidification, freshwater eutrophication, human toxicity, freshwater ecotoxicity, marine ecotoxicity, natural land transformation and fossil fuel depletion. All inventory data were obtained from the information provided by the NAMASTE consortium members. Process yields and materials use have been scaled up from laboratory and pilot-plant results. For energy consumption, the data has been calculated from theoretical values, bibliographic values and industrial unit nominal values. Background data has been obtained from the Ecolvent 2.2 database.

As for the results, when comparing the developed products, cloud production has the lowest level of environmental impact while the
Economic assessment
Economic assessment has been performed using the Full Cost method. Once estimated, it could be useful to complete the economic analysis with a comparison of the references prices for similar technologies already on the market. The HPH citrus paste is a new product; accordingly a reference price was obtained from an oven baked product currently on the market in Italy. Considering the market price of said product, namely 1.85 EUR/280 g, and the fact that the paste constitutes a third of the finished product (excluding packaging) it is hence possible to make comparisons with the cost of the Namaste citrus paste product. However, it is not presently possible to obtain a reference price for a liquid version of the HPH paste. The comparison will allow highlighting the affordability of the three processes.

Finally, although we would have liked to analyse the profitability of the three processes developed process in the NAMASTE project, by using well-known profitability criteria such as gross margin and break-even analysis, Net Present Value (NPV), return on investment (ROI), unfortunately the necessary data for this step was not available at an industrial scale. The availability of such data would have permitted to calculate a single- and multi-objective optimization to maximise the profit and/or minimise the cost of each process.

On the basis of the information acquired from the NAMASTE partners a strategy was developed to scale up the NAMASTE research results to a hypothetical industrial scale. The strategy involved setting production objectives for the three processes which gives the size of the hypothetical new processing plants in terms of the processing of by-product (in tons/year), the determination of number of staff, work hours and equipment required for the processing.

It was hypothesised that annual citrus by-product volume was approximately 72000 t to be allocated as an input into several alternative production processes:

A. 50 % Fibre 50 % Cloud;
B. 50 % Fibre 50 % Paste;
C. 50 % Cloud 50 % Paste;
D. 100 % Fibre, 100 % Cloud, 100 % HPH Paste

The results of scenarios A, B, C for the economic analysis of the three NAMASTE processes have been compared with the reference market prices of 6 EUR/kg for fibre and a range between 1 EUR/kg to 4.785 EUR/kg for cloud (data provided by the NAMASTE industrial partners).

The market price for dry Citrus Fibre is 6 EUR/kg whilst according to our calculation the Namaste price was approximately 6.88 EUR. Considering the approximations required undertaking the calculation, the gap between the market price and the identified price for the Namaste product can be reduced either by modifying the hypotheses used or by improving the production process (i.e. ethanol consumption). The results for the cloud agent are economically sustainable referring to a market price which ranges from 1 EUR/kg to 4.78 EUR/kg. Hypothesis A seems to be the most affordable one while hypothesis C is also potentially affordable if we consider production yield as a basis to calculate common costs (i.e. 3.51 EUR/Kg).

The reference for the paste, as mentioned above, was 1.85 EUR/280 g. Based the information obtained from the Namaste research team, a hypothetical packaged product contains approximately 84 g of paste (in a product weighing 280 g, not including packaging). Outside the product costs related to promotion, transportation, mark-up etc., the approximate cost of the actual reference product becomes 1 EUR (or slightly less). Accordingly, the paste must not cost more than 0.30 EUR as it must substitute around one third of the finished product (excluding packaging). The paste must hence be 0.30 EUR/kg. Hypothesis A seems to be the most affordable while hypothesis C is also potentially affordable if we consider production yield as a basis to calculate common costs (i.e. 3.51 EUR/Kg).

The reference for the paste, as mentioned above, was 1.85 EUR/280 g. Based the information obtained from the Namaste research team, a hypothetical packaged product contains approximately 84 g of paste (in a product weighing 280 g, not including packaging). Outside the product costs related to promotion, transportation, mark-up etc., the approximate cost of the actual reference product becomes 1 EUR (or slightly less). Accordingly, the paste must not cost more than 0.30 EUR as it must substitute around one third of the reference product. The results referred to in Table 4.2 and Table 4.3 demonstrate that for hypotheses B and C the cost for the paste is only slightly higher than the cost of the similar ingredient in the reference product (variation from 0.35 EUR to 0.38 EUR/280 g). For hypothesis D, the cost is between 0.23 EUR and 0.25 EUR/280 g and is hence a more sustainable solution for the product in question.

In light of the market prices, the economic sustainability of the processes is attainable in the production hypotheses A, C and D.2. Some factors are to be considered for future developments. On the one hand, production of pellets for animal feed is a low added-value product. Landfill is not a real option due to the objective of Directive 1999/31/EC on the landfill of waste which tries to prevent or reduce as far as possible negative effects on the environment. Therefore the comparison has to take into account the economics and legal aspects of each process to evaluate the feasibility of the solutions. Furthermore, some of the proposed solutions have several products, and even if the assessed impact for one ton of raw material present bigger values, from the point of view of products impacts can be distributed among them. Also some process, such as cloud and fibre production, can be integrated in a single process allowing increasing revenues, decreasing and distributing impacts.
Market opportunities assessment

Market opportunities assessment has been performed through a web-based stakeholder consultation. The market opportunities of the NAMASTE product were studied by different approaches: A) Desk research was carried out to review the actual market, scanning databases for the available products or for the suggested applications. B) An industry survey was carried out, where the respondents had a possibility to study the specification of the Namaste products and to evaluate the product characteristics, quality, safety, of citrus fibre, citrus paste, cloud and antioxidant extract for feed. C) Conjoint method was used to define the optimum combination of features of the final products for market success from the consumers' point of view. The research contributed to the identification of requirements of the target market, reaching the real target group and to the communication of the advantages of the products to the consumers. The online survey and the conjoint analysis was carried out in Hungary and in India for the drink products that have considerable market potential and the interest of European and Indian consortiums. Besides testing the product ideas, new attributes of the ingredients were presented with specific focus on the sustainability aspects of ingredients gained by by-product processing. The review of trends and innovations in the food sector and the successful product application showed the NAMASTE ingredients with health promoting effects are in line with the actual trends and can have promising market potential. The consumers are more conscious about healthy living and well-being and put more emphasis on the foods with nutritive values, improved quality and diversity. The following characteristics were identified: FIBRE has beneficial effects on the intestinal function and high-fibre diets also tend to be less “energy dense”. The results suggest can be successfully applied in food and beverages or in supplements as well. CLOUD provides better texture and improves the quality of the drink product, while it is still a natural product obtained from citrus peel, which is an advantage. ANTIOXIDANT extracts obtained from peel are natural flavonoids and carotenoids that have potential health benefits and ability to scavenge free radicals. These characteristics can be potentially valorised in beverages, supplements, animal feeds and in cosmetic products as well. PREBIOTIC OLOGOSACCHARIDES and PREFERMENTED BRAN with antioxidant properties also have beneficial intestinal function. For the Namaste wheat bran based fibre concentrate the market potential can be similar but with the ‘advantage’ that it is a neutral fibre source with reduced energy content.

The acceptance of four NAMASTE products was assessed in business-to-business environment, in order to collect information from the target/potential purchasing/ group through consultation with industry.

- The companies use fibre for the improvement of the nutrition profile (66.7 %), followed by thickeners (33.3 %) texture improvement (26.7 %) and moisture management (26.7 %). Most of the companies indicated that the debittered citrus fibre produced by the NAMASTE project fits their quality requirements. Only 40 % of the participants noted that the natural citrus fibre produced by the NAMASTE project fulfil their requirements.

- Some companies evaluated in a questionnaire survey the Namaste antioxidant extract and its potential application in feeds. The companies indicated that they mainly use antioxidants to prevent rancidity in feed. 75 % of the respondents found the information provided about the NAMASTE ingredient satisfactory.

- None of the respondents uses citrus paste in their products but they mentioned based on the specification that this ingredient could improve the texture, the stability of the fillings and the nutrition profile. 60 % of the companies found the information provided in the product specification satisfactory.

- The specification of the proposed clouding agent ingredient provided satisfactory information and fitted to quality requirements of the respondents.

Most of the companies expressed they would use the proposed ingredients only in case of successful evaluation in trials. Conjoint analysis was used for the different drink products (100 % fruit juice, 5 % fruit drinks, fruit smoothies) containing NAMASTE ingredients. This study was carried out in India and in Hungary using the same concept/approach. The NAMASTE project benefitted from the co-operation of the two consortia and valuable information was provided about the market potential of food prepared with ingredients based on by-products in both countries. The main conclusions are:

- 100 % fruit juice was preferred to the other two products. This preference to the fruit juice may have reflected consumers’ health awareness and their demand for healthy drinks.

- Overall, respondents from the Indian market placed higher importance to the ‘ingredient’ levels (e.g. dietary fibre, polyphenol antioxidant and clouding agent; attribute importance: 16 %) than Hungarian respondents (attribute importance: 8.0 %). Their preferences were found to be related to their knowledge of the ingredients, where Indian respondents preferred ‘dietary fibre’ and Hungarian respondents preferred ‘polyphenol antioxidant’.

- Respondents of both markets preferred the benefits to ‘enhance the product nutritional value’. This was followed by the benefit to ‘reduced the environmental impact’.

Results of the attitudinal questions revealed that both markets have a good level of awareness of the environmental issues and a large proportion of respondents expressed positive views towards the ingredients produced from by-products and, subsequently, the market is quite high, approximately 23 €/kg.
environmental and nutritional benefits.

WP6 - EU India Integration

The joint programs Namaste-EU and Namaste-India developed a shared approach/protocol for obtaining food and fish feed ingredients from comparable fruit and cereal processing by-products. Besides practical mutual interactions (exchanges of scientists and protocols, joint meetings, etc.), experiences from both consortia contributed to the elaboration of a general food-chain approach for the development of ingredients/food products based on food processing by-products, consisting of the following steps: 1) Food chain flow scheme analysis, 2) Chemical and biological composition analysis, 3) Potential applications, 4) Technological options, 5) Practicality, 6) Selection of strategies and technologies for valorisation, 7) Process and product development. The advantages and impacts of this approach are described in detail in the section Potential impact (4.1.4).

The project has put in evidence some significant differences between the European and Indian markets. While in India the consumer pays more attention to the functionality of the ingredients (health benefits), probably because of the influence of the traditional natural medicine in their culture, in Europe the technological properties of the ingredients are more important, as it was concluded from the conjoint study. Also the EU regulation is much more restrictive in respect to the nutrition and health claims, which makes that every development of functional ingredients consumes much more time and R&D effort. Bio-actives and functional ingredients like those developed in NAMASTE (anthocians, polyphenols, carotenoids, etc.) have revealed a big interest among the Indian Industrial Platform (IP) collaborators.

Active co-operation of industries is essential in especially steps 4 to 7 of the Food-chain approach. Industries’ commitment in India, however, was minimal at that stage because of lacking funding for their efforts in the Namaste project. This limited practicality of the Indian results compared to the European results. In order to help recover industries’ commitment the NAMASTE EU consortium took actions to intensify collaboration of the Indian consortium with industries. As part of this, CCH in close co-operation with Indian partners organised a business trip to activate new parties. The external experts’ round table discussion and the visit of 4 Indian companies provided an opportunity to discuss the further potential collaboration possibilities. The visit included the organization of training for the Indian project partners that contained subjects having interest for a wider audience beyond the results of the NAMASTE project but related to them, such as successful product and process development practices, EU food safety and quality requirements of the EU buying organizations, research efficiency. The barriers of the knowledge exchange also were discussed and measures were presented to tackle them.

As result of the collaboration between EU and Indian partners, interesting results have been obtained by UAS on using the various by-products in aquaculture feed. The Namaste India’s focus fruit processing by-products (mango and pomegranate) were proven to be only fairly relevant for fish feed (relevant source of carbohydrates and functional compounds, but low protein content). However, the Namaste EU focus fruit processing by-product (citrus) was found to be more interesting, specifically for ornamental fish (contributing to ornamental properties as well as a source of carbohydrates and functional compounds with clear important health benefits for the animals).

There were some constraints regarding the possibility of directing young Indian scientists to Europe. However it was managed to organise exchange of Indian researchers to UniBo, IFR and AZTI with focus on using/learning about experimental methods for by-products (component analysis, extraction and processing). Two researchers from AZTI visited the experimental facilities of UAS in Bangalore. AZTI and UAS designed a detailed working plan for a EU researchers visiting scientist of UAS, whereas UniBo and GLP planned visits related to market analysis. However, these visit failed finally due to unforeseen administrative problems in India, and were replaced by the business trip to activate new parties (see above).

On the level of work packages, knowledge on processing protocols were exchanged between India/Europe and research activities were carried out so that common publications can be prepared.

Other achievements / actions that facilitated the cooperation and the effective implementation of the project:
- A database with experimental facilities has been constructed and shared between NAMASTE EU and Indian consortia.
- During the course of NAMASTE project a total of 40 companies have been recruited for the IP in the different workshops organised by the local members.
- 3 IP workshops were organised in Bangalore (India), Barcelona (Spain) and Barcellona Pozzo di Gotto (Italy).
- Two joint position papers on by-products from food processing and the food-chain approach for generating food ingredients from by-products were prepared.
- 7 joint NAMASTE newsletters were prepared in close cooperation by the NAMASTE EU and INDIA consortia.

Potential Impact:
The technologies developed in the NAMASTE project provide novel solutions for the management of the high amounts of by-products generated by the current food processing practices. Innovative technologies have been adapted for the stabilisation of citrus peels and for obtaining valuable ingredients from them, such as fibre, polyphenol extract and clouding agent. Procedures were developed for production of fermented wheat bran and oligosaccharides from wheat bran which need further testing for scaling up. These ingredients can be used for the development of a range of new food products. Technologies developed contribute to the improved exploitation of available biological resources generated by raw material production. Thus they can reduce the environmental impact associated with food production. These technologies and ingredients will be used as demonstration examples of the viability of the concept of valorisation of by-products of food processing. Also demonstrated is the potential benefits of an approach whereby the food raw material as a whole is considered as a source of valuable materials and ingredients, which can be obtained and separated at different stages along the food chain. This requires the implementation of appropriate handling practices and processing technologies. The results and experiences of the NAMASTE project (the EU and the Indian parts both) highlighted that the current food processing, by-product exploitation and waste handling practices should be reconsidered and revaluated. There is an identified need to develop a concept of harmonising the aspects of cost effective production of safe foods, best use of biological resources, reduction of environmental impact, to support local employment and meet consumer expectations. These considerations should be applied individually for each food chain by considering the specific properties of the raw material, the geographical location and structure of the food supply chain and the consumer expectations and attitude towards the different products and processes. This can be carried out by applying a systematic food chain approach.

Food chain approach for the valorisation of citrus and wheat processing by-products

The food chain approach includes the following steps:

1. Food chain flow scheme analysis: evaluate the food chain and the by-products and wastes that it generates at different steps (quantities and qualities, including potency of food or feed-grade status, alternative chain structures based on different combination of similar steps);
2. Chemical and biological composition analysis: detect contaminants and identify valuable components and estimate/determine their contents in the by-products;
3. Potential applications: identify potential/promising market/application areas for targeted by-products or extracted components;
4. Technological options: identify potential technologies for sorting, grading, stabilising, extraction and/or transformation to generate identified products from the by-products. Evaluate their technological applicability, yields and selectivity, impact through environmental and economic assessment;
5. Practicality: analyse food/feed safety and hygiene risks including legal requirements, and analyse the structure and the sustainability of the food chain and as well as its benefits (volume and value of the by-products, seasonal generation, costs, business risks, impact on employment, etc.);
6. Selection of strategies and technologies for valorisation: prioritise options based on aforementioned analyses;
7. Process and product development, also addressing food safety, sustainability issues, consumer acceptance and marketability, cost implications for users including setting up a strategy for manufacturing, marketing and business growth.

In the NAMASTE project it was established that food-chain approach can help the development of ingredients / food products based on by-products. This approach was tested on citrus and wheat processing by-products but is also relevant to a wider range of plant-based by-products generated by the food processing industry.

Impact on the compliance to the European Food Quality and Safety regulations and trade standards

Based on the results of the NAMASTE EU FP7 project, a list of recommendations was developed which summarized the recommended general considerations and practices for the food industry to achieve compliance to the EU requirements on food safety and quality of ingredients made of by-products of plant origin. These include the use of a HACCP study extended with a simplified, documented risk assessment for the hazards associated with the use of by-products and the benefits of using raw materials from integrated/assured production systems. There is a need to:

- start with more stringent controls until satisfactory evidence is collected to confirm that Good Agricultural Practices (GAP) provide the necessary level of food safety
- use extended supplier quality assurance system for the raw material supplier for food processing at the by-product processing stage
- handle all by-products according to food hygiene requirements if they will be used as a source of food ingredients
- consider consumer education, etc.

Food industries have a preference to use such technologies for valorisation of by-products, which are counted as new and not as novel. This makes it unnecessary to provide additional specific evidence to prove that these ingredients are appropriate for human
consumption. Food industries are also mostly reluctant to invest in products and technologies resulting in “novel foods”. The experiences of the NAMASTE EU project showed there are several opportunities to obtain new ingredients and other valuable compounds which do not fall under the scope of application of the novel food legislation. For example none of the new ingredients made of citrus peel and wheat bran, and the finished products used for demonstration of the applicability of those ingredients, neither the technologies nor the protocols were identifiable as novel foods.

It was established that ingredients made of by-products such as citrus peel and pastazzo and wheat bran do not represent an increased health risk for the consumer than those main food products with which they are generated during processing. This estimation is valid until the raw materials from which are generated comply to the actual EU food legislation and appropriate control measures based on Good Agricultural Practices and Assured Systems are applied during their production. The applicability of these assessments should be validated with real data from the specific raw material supply and processing operations. The processes developed for the production of citrus fibre, citrus paste, clouding agent, polyphenol extract, fermented wheat bran, oligosaccharide and their presented alternatives are considered able to produce safe ingredients. There is no reason to anticipate that compliance to the relevant legal requirements cannot be achieved.

Recommendations for good practice and practical examples help not only the food businesses dealing with the valorisation of by-products made of citrus peel and wheat bran to achieve and verify compliance to EU food safety requirements and quality requirements of legal and private trade standards, but also facilitate other industries working on exploitation of plant based by-products from food processing to achieve compliance.

The method developed for assessing the food safety of experimental samples for tasting, as produced in experimental facilities not approved for food production, ensures that necessary food safety control measures are followed during their production and for protection of the health of professional staff and consumers participating in the tastings. This can enable a faster and more effective product and process development at food business, research organisation and university level and can contribute to an increased competitiveness of food businesses dealing with by-product and indeed other areas of food processing. The application of this procedure provides particular benefits for experimental facilities used for multiple purposes – different kinds of food materials and non-food materials, which can cross-contaminate each other.

Impact on the competitiveness of the industry
The functional properties of citrus fibres and their potential antioxidant activity make them good candidates for future commercial exploitation. This is enhanced by the positive sensory evaluation obtained through sensory tests. Similarly, the positive prebiotic index (PI) obtained for wheat bran-derived oligosaccharides has demonstrated how arabinoxylan-derived oligosaccharides with high PI can be obtained for commercial and health-promoting exploitation.

The economic evaluation of the processes and technologies developed within the NAMASTE project for the citrus by-products proved that by-product processing can significantly contribute to the financial viability of such food processing activities where a relatively small part of the raw material is used for the main product (40-50% at citrus juice production). Exhaustive cost analysis has been done due to high differences observed in the processing cost and final product market prices. For instance, despite the very low margin obtained from selling the dried orange pellets, it contributes to the overall profitability of the citrus processing since it offsets the high waste management cost (30 ~ 40 €/tm).

Although problems remain to optimize production of ingredients for commercialization, results demonstrate the potential to exploit the green technology approach of NAMASTE to produce new, safe and health-promoting food ingredients from food processing by-products. This should have a positive impact on the future development of the food industry sector.

Impact on the employment
The valorisation of the fruit and wheat processing by-products may contribute to the generation of new jobs. The contribution of the defined valorisation options to the sustainability of the involved industries would also contribute to the stability of the already existing jobs and also increase the competitiveness of the European juice sector face to the biggest producing countries in the world (almost 80% of the orange juice consumed in Europe comes from Brazil).

Environmental impact
Among the solutions proposed by the NAMASTE project for the valorisation of food by-products, three selected processes, namely the production of citrus fibre and polyphenol extract, a clouding agent and (HPH treated) citrus paste, were scaled-up and evaluated for environmental impact.

Life cycle assessment (LCA) has been performed in order to foresee and compare their environmental impact and their results have been compared with current on-going solutions, landfill and cattle feed. When comparing LCA results of the developed products per tonne of by-product processed, cloud production has the lowest environmental impact values while the HPH paste has the highest. Due mainly to the higher energy consumption of the newly developed solutions, cattle feed and landfill have lower values. However, landfill
is against Directive 1999/31/EC which tries to prevent or reduce as far as possible negative effects on the environment, and cattle feed has a very low or no added value. Moreover, other considerations, such as products avoided, can improve LCA results of developed processes. Also, process optimization and integration with the subsequent improvement of energy and materials consumption is still to be performed when scaling up the procedures developed at lab scale, which would also probably improve LCA results.

In any case, it must be noted that from an environmental perspective, the best option is to add value to by-products of food processing. The conversion of the by-products into valuable ingredients and compounds and then using them in value-added food products can provide opportunities for at least recovering the processing costs, reduction or elimination of the waste management costs and also to make some additional profit.

Impact on EU-Indian research collaboration and market development

The training courses carried out in Bologna and Bangalore provide an insight into successful industry practices for the young scientists and SME entrepreneurs. Most of the participants appreciated the co-presentations on understanding industry needs, the practical steps and aspects of product/process development, food safety and traceability systems. Benefits of knowledge transfer and transnational team work and cooperation were also highlighted, which can enhance the participation of young researchers and SMEs in research and innovation networks and the collaboration of food businesses and researchers on exploitation of research results. During the open discussion with industry experts and project partners after the Indian training course further collaboration opportunities were identified.

On the NAMASTE training in India the legal requirements and trade standards of the European Union on food safety and consumer information were presented, that helped participants to understand what is expected by EU trade partners. The researchers of the NAMASTE EU also gathered information about the Indian food industry that helps to better understand their needs and facilitate effective collaboration and technology transfer. The European and Indian teams developed personal professional links which can a good basis for further collaboration.

Attitudes and ethical issues related to products prepared with by-product ingredients

The procedure adapted for ethical assessment of ingredients and compounds gained from by-products and for the products thereof used for human consumption can be applied in several other research and development activities aimed at valorisation of by-products for human consumption. It is an ethical requirement that consumers should be informed about the origin and nature of these ingredients, e.g. that certain ingredient are made of by-products to enable them to make an informed decision on purchasing and consumption. There are significant concerns in certain consumer groups related to the consumption of foods made of ingredients obtained from by-products. Consumer concerns related to the consumption of these products can be reduced by consumer education. The main arguments include the followings. Until edible parts of the food grade raw material are handled as food, e.g. the compliance to food hygiene requirements is maintained, they are considered food components, not wastes. Therefore, neither the food hygiene nor the emotional concerns “on eating waste” are realistic. There are several examples in conventional and also in traditional foods where by-products are accepted or even consumed for their specific sensory character or health supporting properties. Typical examples include potato skin, citrus peel, wheat bran in bakery products etc.

The consumer surveys carried out in India and Hungary in the framework of the NAMASTE project revealed that that consumer in both markets had good awareness of the environmental issues and they expressed willingness to purchase products that used ingredients arising from by-products. The conjoint study of NAMASTE drink products showed that in terms of product type, in both countries the100% fruit juice is preferred over the other fruit drink products (smoothies and 5% fruit drinks) when using extracts from by-products. Comparing the three by-products extracts (dietary bre, antioxidant extract, clouding agent), the dietary bre is preferred over the other extracts in India, while using antioxidant extract was most preferred in Hungary. Considering the nutritional, sensory and environmental benefits, enhanced nutritional quality is preferred over the other benefits. The results showed that that the people are more conscious about healthy living and put more emphasis on foods with nutritive values, therefore the NAMASTE ingredients can have a promising market potential.

Main dissemination activities

The project dealt with valorisation of citrus and wheat processing by-products so the end users and the target audience were people with an interest in the sustainability of the food chain, through utilization of raw material and processing by-products and concerns with the long-term viability of citrus and wheat processing by-products. This includes: food manufacturers; ingredient suppliers; soft drink producers: bakers; millers; feed formulators; equipment manufacturers; food wholesale / retail sector; biotech industries.

During the project the project partners participated in several conferences, workshops and events and several publications and articles were developed by them. The personal meetings, discussions are a very effective way of disseminating the project results. Besides the open days, the results of the project were also shown (e.g.: by using the research summary sheets or the core dissemination material) on personal meetings or company visits. In order to raise the public awareness, different methods are being applied, such as invitation...
of the media, web-sites and popularized publications (brochures, newsletters, leaflets). Due to these activities the project got publicity the intended users and stakeholders.

Till the end of July 2013 the following activities were carried out during different workshops, conferences and events:

- 8 presentations on European and National meetings of National Technology Platforms “Food for Life” and the meetings of industry associations,
- 10 presentations on workshops
- 7 presentations on open days for industries
- 7 personal meetings with industry (visiting or hosting companies)
- 7 Research summary sheets and 4 core presentation materials were developed
- 20 presentations at conferences
- 2 scientific article
- 2 trainings (in Bologna and Bangalore)
- 7 joint newsletters with NAMASTE India
- 3 articles
- 3 interviews
- 17 press releases
- 1 webinar
- information on the project participants’ web pages and the homepage of the project
- 2 presentations in an easily understandable popular style
- 1 leaflet for consumers

List of Websites:

The homepage of the NAMASTE project: http://www.namaste-eu-india.org/

Coordinator: Prof. Fabio Fava UNIBO (fabio.fava@unibo.it)

WP2 Leader: Dr. Carlos Bald AZTI (cbald@azti.es)

WP3 leader: Prof. Keith W. Waldron IFR (keith.waldron@ifr.ac.uk)

WP4 leader: Dr. Lucia Vannini UNIBO (lucia.vannini2@unibo.it)

WP5 leader: Dr. Aintzane Esturo AZTI (aesturo@azti.es)

WP6 leader: Dr Jan Broeze DLO-FBR (Jan.Broeze@wur.nl)

WP7 Leader Dr. Andras Sebok CCH (a.sebok@campdenkht.com)

Project Manager. Dr. Alessandro Zamboni UNIBO (a.zamboni@unibo.it)

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