**Final Report Summary - PLEASURE (Novel Processing approaches for the development of food products Low in Fat, Salt and Sugar)**

Executive Summary:

More than 60% of all reported diseases in modern industrial countries are said to have their origin from malnutrition. Fat, salt and sugar fulfil important functions in the food processing and also in the human metabolism, but meanwhile, these compounds represent also an important cause in the prevalence of malnutrition, their excessive consumption leading to enormous health problems. Therefore, there is a strong need in finding solutions to develop suitable food products to overcome malnutrition caused by the high consumption of fat (saturated and trans-fatty acids), salt (sodium) and sugar (mono- and disaccharides). In the past years many attempts, mostly considering the use of replacers, for reducing the fat salt and sugar content in different food products were made, but with only limited or even no success. Saltiness, sweetness and fat perception are strong markers of the sensorial attributes and therefore also of the consumer acceptance of the product. The PLEASURE project is having a unique approach as it addressed the challenges involved with producing food low in fat, salt and sugar, from the processing side, avoiding the use of replacers. Therefore innovative approaches, processes and novel technologies were developed and/or implemented, within the project, allowing thus the production of new microstructure reduced-in food products with similar sensory properties as the conventional ones. Physical structuring, biotechnological processing and the in depth understanding of the location of salt and sweet tastants in a complex food system, were the main conceptual routes used by the project for developing the reduced-in foods. The PLEASURE developments were addressing initially the “mono food” systems (bakery, cheese, meat, and fruits & vegetables) and afterwards were further expanded to more complex food systems such as ready to eat meals (pizza, puffing pastry with meat filling and puffing pastry with sweet fruit filling), reduced-in products being successfully obtained for each of the food categories. The PLEASURE reduced-in products were evaluated by non-trained naive consumers, within a large international consumer test comprising five different European countries (Germany, France, Spain, Romania and Ireland), overall being well perceived and accepted by the consumers. In many cases the reduced-in food products developed were not identified at all as containing less fat, salt or sugar, quite often the sensorial perception and the acceptability of these components being rated even higher than the conventional products, making thus the PLEASURE project successful. The PLEASURE project generated in depth knowledge regarding the relationship between aroma and sensory perception, on this purpose, a model mouth (in vitro masticator) comprising specific functionalities that allow an analytical approach of tastant release during mastication, being also developed. Further, the development and demonstration of three prototype equipments (low pressure dough mixer, dough sheeter and bioreactor) are representing other important achievements of the project.

Project Context and Objectives:

Since the early 90’s, an epidemic growth of dietary induced diseases has been observed among the European population. While at the beginning, many of those diseases where related to the continuous ageing of the population, nowadays more and more average citizens and in particular children and adolescents are concerned. More than 60% of all reported diseases in modern industrial countries are said to have their origin from malnutrition. Malnutrition causes besides negative health impacts, also enormous macro-economic consequential-cost, primary due to exploding cost for the health care system. It has been identified that, an important cause in the prevalence of malnutrition, is represented by the high consumption of
fat, salt and sugar. Fat, salt and sugar fulfil important functions in the human metabolism but meanwhile their excessive consumption is leading to enormous health problems. The important role which these compounds are playing in the food processing, in conjunction with the consumers trend towards processed and convenience food (ready to eat meals) represent the main cause of the overconsumption of salt (mainly sodium chloride), fat (saturated and trans-fatty acids) and sugar (mono and disaccharides). Therefore the European food industry is confronted with a lot of criticisms. It is a challenge for the food industry, of which are 99% SMEs, to develop new products in order to serve the consumers demand for convenience products which are reduced in salt, fat and sugar and to provide products of high quality (mainly taste & texture in this context) and safety at low price, at the same time. To achieve the above, many of these products necessitate fat, salt and/or sugar – either as a processing aid, for taste & texture or for preservation purposes. The main approach used by the food industry for reducing the fat, salt and sugar content in food products is mostly based on the application of replacers, while very little progress and innovation was done through technology, clearly underlying the fact that the track of processes and technologies is thus under explored. Besides this, the application of replacers is often associated with some negative aspects such as low consumer acceptance due to several aspects such as the increasing consumer demands for “Clean Label” food products, negative impact on the food texture leading to a different mouth feeling not accepted by the consumers, off flavours, aftertaste, risk of intolerance or allergies, etc. Under this context, the PLEASURE consortium (16 partners from 8 different European countries) joined forces, and addressed the challenges involved with producing of food low in fat, salt and sugar from the processing side, while at the same time avoiding (or where not possible, reducing) the use of replacers. Therefore the PLEASURE project came as a response to the need of finding suitable solutions to overcome malnutrition caused by the high consumption of fat, salt and sugar, and by developing innovative processes and/or implementing novel technologies, PLEASURE allowed the successfully development and production of new micro structured and naturally reduced-in (fat, salt and sugar) foods with similar sensory properties compared to the conventional ones. For achieving its aim the PLEASURE project followed three main routes:

- Physical structuring for fat and salt reduction
- Biotechnological processing for sugar reduction
- In depth understanding of the location of salt and sweet tastants in a complex food system

The PLEASURE developments were firstly addressing to “mono food” systems: Bakery (pizza dough and puffing pastry), Cheese (Mozzarella style cheese), Meat (Bologna type sausage, cooked ham and dried cured sausage) and Fruit & Vegetable (e.g. apple, cherry, tomato preparations) and afterwards were further broaden to more complex food systems, namely three Ready-To-Eat (RTE) meals: pizza, puffing pastry with meat filling and puffing pastry with sweet fruit filling. The three ready to eat meals were based on the mono food systems which have been previously optimized. Against the above said, the overall objectives of the project consisted in the development of new processing approaches and tailor-made technologies for the use of small and medium sized (SME) food producers to produce healthier food for the European consumer. The idea was to identify and further develop (novel) processes and processing technologies which on the one hand allowed the reduction of the unwanted fat (saturated and trans-fatty acids), salt and sugar (mono- and disaccharides) but on the other hand avoided or at least reduced the use of replacers, by achieving an optimized sensorial perception of salt, fat and sugar into the products developed.

To achieve the overall project aim, six main interdisciplinary Scientific & Technological objectives were established as described below:

S&T Objective 1- Research and development of indexes for the objective measurement of the reduction in sugar, salt and fat (saturated and trans-fatty acids) content

The aim was to research and develop different indexes for the objective measurement of the sugar, salt and fat (saturated and trans-fatty acid) content. The major advantages in working with such indexes, based on a reference value, lies in the fact that they are easily transferable to any new legislation without any changes necessary to bring to the ongoing labelling rules. These indexes range between 1 (reference value for the reference food) and 0 when the ingredient is equal to zero, one of the project novelties lying in the combined index that can address one value for two different components (e.g salt and sugar).
S&T Objective 2 - Research and development of processes and technologies for the production of bakery products low in saturated fat, sugar and salt

For this objective the PLEASURE project was focused on Pizza Dough (PD) and on LPP (Laminated Puffing Pastry) as model systems.

A model dough system with salt, sugar and fat in the range of PD and LPP was considered first to better understand the impact of granulometry (e.g. salt), processing (mixing-sheeting-baking), and enzymatic reaction, on sweetness and saltiness. Further, real pizza dough was considered, specific mixing and lamination conditions as well as the respective innovative equipments being developed for reducing the salt and sugar content. For the reduction of solid roll-in fat, in puffing pastries, the adjustment of the processing parameters, the use of specific sheeting programs as well as the influence of different fat blends, were some of the important aspects that had to be considered and investigated.

In relation to this objective, PLEASURE aimed to develop a pizza and puffing pastry dough together with the related manufacturing processes and technology, which fulfils the labeling criteria of “reduced in fat/salt/sugar” as set in the EC regulation no 1924/2006.

S&T Objective 3 - Research and development of processes and technologies for the production of meat products low in fat (saturated and trans-fatty acids) and salt

This objective comprised the design of model systems which were further used to evaluate process induced structural changes of proteins as well as for identifying the optimum processing conditions, for allowing the production of reduced-in meat products. Recipes and processing conditions were developed to replace functional ingredients by processes, in order to condition the functional properties of the raw material. Systematic studies of process-product interactions, incorporating also novel technologies such as of high pressure treatment (in case of increase saltiness perception) were addressing three different types of meat products: Cooked Ham, Cooked sausages (bologna-type) and dried cured fermented sausage.

Therefore, within this objective it was aimed the development of meat products, together with the related formulations and process condition, able to fulfil the labeling criteria of “reduced in fat/salt/sugar” as set in the EC regulation no 1924/2006.

S&T Objective 4 - Research and development of processes and technologies for the production of cheese products low in fat (saturated and trans-fatty acids) and salt

The overall aim here consisted in combining scientific know-how and bioprocess re-engineering in order to optimize the quality of reduced-fat, reduced salt (sodium) Mozzarella-style cheese, by using advanced technological processes such as protein separation and transformation, new cheese texturisation approaches, flavour enzymology, etc.

The target reduction was of -30% each for salt and fat (EC regulation no 1924/2006), using the novel technological approaches developed while accomplishing acceptable cheese texture and functionality, comparable with the typical characteristics of commercial benchmark cheese such as part-skimmed Mozzarella, typically used in pizza.

S&T Objective 5 - Research and development of sugar, salt and fat (saturated and trans-fatty acids), reduced sauces for the use in Ready-To-Eat (RTE) meals

Sauces, in fatty/salty but also in sweet forms, are a universal component for RTE meals. The PLEASURE strategy was mostly focusing on two different technological approaches. For the sugar reduction, a combined biotechnological platform based on enzymatic and fermentative reactions (plus the adapted equipment -bioreactor) had to be developed. In the case of fat sauces, physical technologies like high pressure homogenisation had to be applied in order to modify the microstructure in the sauce emulsion systems for enabling a more intense salt perception as well as for allowing the application of higher concentrations of healthy unsaturated fats. Research on model sauce systems with reduced sugar, salt and saturated and trans fat content were carried out to better understand the impact of structure (emulsion and aerated products), processing (pressure technologies), and enzymatic and/or fermentative action on texture (related to fat content perception), sweetness and saltiness. Sauces such as mayonnaise, tomato as well as different fruits puree were considered for reducing the fat, sugar and salt in order to fulfil the labeling criteria of “reduced in fat/salt/sugar” as set in the EC regulation no 1924/2006.
S&T Objective 6 - Research and development of RTE meals (pizza and puffing pastry) composed of the mono food systems from S&T objectives 2 to 5 reduced in the salt, fat (saturated and trans-fatty acids) and sugar content while maintaining the saltiness and sweetness perception and mouth feeling attributed to fat.

This objective was embedding the results obtained within the previous objectives. Much focus was set on modulating the spatial distribution of salt and sugar content in the different ingredients while keeping an acceptable perception of saltiness or of sweetness. Development of three different ready to eat meals were considered within this objective:

- A pizza including pizza dough, a tomato sauce, meat and cheese.
- A puffing pastry with a meat filling
- A puffing pastry with a sweet filling (fruit puree)

The final validation of the RTE products developed within this objective was carried out through an international consumer acceptance study.

Besides the above mentioned S&T objectives within the project much effort was set on performing appropriate activities for successfully demonstrating and disseminating the PLEASURE achievements. Further for ensuring a smooth implementation of the project in order to achieve its goals, a strong coordination and a high level of communication at consortium level had to be implemented.

For a project of this nature and scope, the selection of the partnership and compatibility and complementarities between partners was of high importance. Each and every partner of the present consortium was carefully selected based on their specific competence and potential contribution to the project objectives, without compromising the rigorous criteria of quality and scientific excellence. All partners are well known and very active in their respective business sector. Within the consortium, also the criteria for geographical spread over Europe, as well as the existence of strong links with other science-industry organizations have been taken into account. However, PLEASURE has deliberately taken the decision of not having any industry of ready to eat meals as part of the consortium. Therefore the dissemination of results, especially the ones related to RTE meals assemblies, could have been done without any IPR constrains, ensuring thus a big impact for the benefit of the health of the European population.

Project Results:
In accordance with the above mentioned objectives PLEASURE project activities were organised around 6 RTD work pages (WPs), the main outcomes generated being summarised below. Besides the RTD activities, the project comprised also specific work packages dealing with management, demonstration and dissemination aspects, thus ensuring a smooth implementation of the project, while appropriately validating and constantly disseminated its outcomes.

WP 1 – Materials methods and legislation requirements

WP 1 was focusing on the material and methods and standard operation procedures (SOPs) which had to be used during the project. This WP was also covering the establishment of the methodology to assess the release of salt and sugar during mastication and the setting up of the framework for the sensorial tests which had to be performed during the project.

Furthermore, the tools and the know-how that allowed for better understanding the importance of the food structures on the saltiness and sweetness perception by an individual, were developed.

Among the main S&T outcomes obtained during PLEASURE project, the following points could be stressed out:

In terms of material and methods, one of the challenges was to determine with a great accuracy the salt content of the food items considered. In the sodium chloride, the harmful constituent is the sodium, whereas the salt content is determined by evaluating the chloride content. Specific methods have been used to extract the sodium and the chloride out of the food; this can be challenging for matrices such as cheese and the method of extraction should be adapted to each food matrices. This concerns also sugar and lipids in general. For the salt, different sodium and/or chloride titration techniques have been benchmarked to obtain reliable contents (Inductively Coupled Plasma in combination with Optical Emissions Spectroscopy, potentiometric titration etc). Calibration and bench marking with model solution and matrices is needed to validate the accuracy of the method used. Existing standards should be under scrutiny as they do not always deliver very accurate results.

Sugars are defined in a very general matter in the Nutrition claims regulation which refers to the directive 90/496/CEE where...
it is indicated that sugars are all mono and disaccharides except polyols. Concerning the sugar, different techniques such as HPLC, enzymatic kit have been used. “Sugar” encompasses different combinations of glucose units with different sweetening power. One can distinguish the simple sugar (Monosaccharides) and the complex sugar (Polysaccharides). The usual “sugar“, Sucrose, is a disaccharide made of glucose and fructose. Then comes the oligosaccharides (3 to 9 units) and the Polysaccharides (more than 9 units). In the project it has been considered different sugars and proposed a method to calculate a sugar index that can accommodate the weighted contribution of each sugar based on its sweetening power; pre-test completed, calibration curve on model solution and matrices is done.

For fat, different techniques have been used. Fat is again a very complex topics, once one enters in the detail of the classification of fat (i.e. saturated and non saturated, etc). Within the project, conventional techniques such as GC and gravimetric method were used. Pre-test completed, calibration curve on model solution and matrices was done.

One of progress done in the project was to propose different indexes that have the potential to become in the future, replacers of the values and labeling proposed in the existing regulations on nutrition claims. These indexes are:

- SALI as salt index
- SUGI as sugar index
- SSI as salt & sugar index
- SATI as saturated fat index

These indexes range between 1 (reference value for the reference food) and 0 when the ingredient is equal to zero. One of the novelties lies in the combined index such as SSI which address in a same number the salt and sugar content. One of the challenges in Europe is also to determine the “reference“ value, which is country dependent. So the labeling has to be addressed country by country, which can be a nightmare for the food industry. What PLEASURE proposes, is to use an averaged reference value in Europe to simplify the situation.

Based on numerical applications done on reference foods, based on product specifications, equation combining only SALI and SUGI or equation accommodating SALI, SUGI and SATI have been considered to determine a “mixed index” accommodating at the same time salt, sugar and eventually lipid content in a same food. The SSI Index combining SALI and SUGI appeared relevant because it takes into account salt and sugar content. It highlights the compensation of a decrease of salt content by an increase of sugar content and conversely. This Index is easily applicable and understandable.

The Index combining SALI, SUGI and SATI (average value) can be considered in certain cases, where a decrease of in salt and/or sugar content is compensated with an increase of fat content.

Determination of saltiness and sweetness perception: A very significant step forward has been done by partner ONIRIS who has developed a brand new in vitro masticator able to assess the kinetics of tastant and aroma release during mastication. This new masticator has been successfully compared to in vivo perception even though the overall perception is sometimes difficult to assess accurately without the human perception. This masticator uses artificial saliva which is injected during food chewing. Specific chewing program have been established and differs depending on food structure and composition.

Concerning the food specification, a substantial work has been done in collaboration with EUROFIR to establish a typical European pizza in terms of content of ingredients (considering dough, tomato sauce, ham and cheese) including its nutrition profile. A similar work has been done for puffing pastry. Concerning the assembled food systems such as puff pastry with sweet or salt filling, a reference product has been designed based on the existing products available in the European market. The consumer expectation study has covered one general survey and a specific questionnaire for the demonstration activity with the finalized products. Concerning the general survey, 5 countries have been considered; France, Netherland, Germany, Spain and Romania. As an example, the meaning of the “reduced in” label was not clear at all for all countries, showing that the numerical value approach proposed by PLEASURE was relevant. The clarity and trust of the nutrition claim “reduced-in” was interesting. Half of the Dutch (56%) agree about the clarity and trust of “reduced in”. In Romania and France a low percentage agreed (21.4% and 24% respectively). Spanish at a percentage of 45% distrust the reduced-in clame, on the labels of these specific foods. Germans at a percentage of 54.2% distrust the reduced-in clame, on the labels of these specific foods.
The study on nutrition values investigated dietary intakes of saturated fat, sugar and sodium from eight pre-defined food groups, as well as total diet intakes for both the Dutch and UK populations.

The products evaluated on the PLEASURE project represent a large share in relation to the global food intake. It has been found that the consumption of such product can reach 36% of the population, as in the case of cooked ham or 21% in the case of dried sausages. In the case of pizza dough or mozzarella-style cheese, the food consumption can reach 17% and 18.7% respectively.

The same is true when comparing the current values with the nutritional recommendations. It was found that in general, whether in the UK or the Netherlands, the consumption of these three constituents is higher than the national recommendations. If we look at the consumption of sodium, there is an excess of 13% in the Netherlands and 60% in the UK compared to what is recommended on both countries. Considering an average of 2000 kcal/day and an intake of saturated fat not exceeding 10% of the total energy, both populations have intakes of saturated fat higher to 20%, i.e. more than double. These data highlight the importance and the impact that these reformulated products can have on the daily intake of those populations groups.

The overall aim of the project was to achieve a 30% reduction among all food groups in terms of sodium, sugar and saturated fat. These results were achieved reaching reductions up to 48%, as is the case of mozzarella-style cheese for the saturated fat. The same occurred with the pizza dough, with a reduction of 44% of saturated fat when compared with the baseline product.

With respect to the consumption to saturated fat in grams per day, and when we compare the reformulated foods to the baseline results, products such as mozzarella-style cheese and the puff pastry dough are reduced by 50% (Puff pastry dough (sat. fat): 10g/day to 5.3g/day; Mozzarella-style cheese (sat. fat): 4.3g/day to 2.5g/day).

In some cases, it was noticed that there are some baseline food products that have much higher levels of sugar, sat. fat and sodium (eg. France, Spain, Romania) compared to the ones used for this assessment. This means that the reformulated products may have a higher effect than the ones already stated on this report if we took into account those countries.

Regarding the legislation requirements, a detailed survey on current legislation for the selected food commodities was performed, in order to ensure that the product development complies with legal requirements of European Food Law. The legal requirements for nutrition claims as “reduced in” did not seem to be a blockage for the project. Among the bottlenecks, the use of high pressure processing done on the meat products fall under Novel Food Regulation (EC) No 258/97 concerning novel foods and novel foods ingredients. Some concerned aroused too regarding the implementation of sugar alcohol in the fruit sauces.

WP 2 – Baking applications

Within WP 2, salt, fat and sugar reduction has been investigated by using pizza dough (PD) and laminated puff pastry dough (LPP) as model systems. These dough systems show several similarities such as a high fat content. Even if they slightly differ in salt and sugar content, they are both exposed to high shearing stress during the lamination process and are prone to sticking problems while processing. Fat is playing a key role in puff pastry production, even more than in pizza dough. During the lamination process of the LPP and during baking, fat is separating the many fine dough layers from each other. Salt and fat (flavour carrier) are both important for structure and taste of pizza and puff pastry products. An important objective is a minimum fat reduction of 30% and salt reduction of 25% for LPP and PD to enable the labelling with claims like “fat reduced” and/or “salt reduced” according to EU regulation 1922/2006.

The impact of salt reduction on dough texture properties and dough behaviour during mixing and during laminating was studied. Different strategies for the development of salty micro-domains (late incorporation, incorporation in fat, lower hydration) were applied. Further, the impact of salt and sugar granulometry and the method of incorporation of salt (dry or dissolved) on dough properties, sensory perception and release kinetics (salt) of model PD was studied. Additionally to the changes of the dough structure a reduction of salt will result in a higher water activity and in a subsequent increased risk of mould growth (microbial risk).

Further, the influence of four vegetable fat blends (FB1-FB4) containing different ratios of palm stearin and rapeseed oil (with decreasing amount of saturated fatty acids (SAFA)) on PD and LPP product quality was investigated.
To develop sweetness perception in dough, three amylglucosidase (AMG) contents (0, 0.75 and 1.5g/100g flour) and three different sucrose contents (0, 8 and 17 g/100g flour) were investigated. Therefore, the impact of AMG on dough stability and the impact of sugar addition on the activity of AMG during storage (4 °C, 4 weeks) were studied. Furthermore, the impact of the activity of AMG on rheological properties of a model dough was investigated. The release of glucose (by AMG) in dough was measured by HPLC in function of storage time in order to quantify the AMG activity.

During storage at 4 °C, the AMG was not active because of the absence of substrate. During mixing and sheeting, the substrate (damaged starch) was a limiting factor for the AMG activity and consequently the glucose release was limited by the damaged starch content of the flour. During baking the amount of released glucose was dependant on the amount of AMG used. Moreover, this storage stage before baking limited the AMG activity during baking. The sucrose limited the AMG activity while AMG promoted the sucrose hydrolysis.

The AMG effects on viscoelastic properties of the dough were very small compared to the sucrose effects. Further, sensory (ranking) test was done on sweetness perception of baked products. As a result, it appeared that the use of 0.75g/100g flour of AMG gave equivalent sweetness perception than the use of 17g/100g flour of sucrose (10% dough).

One objective of this study was to determine the amount of salt needed to maintain dough properties for the process. Seven quantities of salt from 0% to 2.1% (flour basis) were investigated to determine the impact of a salt reduction in dough, on its properties during and after mixing. The time needed to reach the maximum of instant power of the tool of the mixer and the temperature of the dough were evaluated during mixing. Measures of extensibility, stickiness and rheological properties were used to characterize the dough properties.

An experimental design has been used to determine the impact of salt reduction on mixing time and mixing energy. Efficient mixing conditions can be defined as conditions for which the temperature rise of the dough is limited to minimal with an efficient transfer of energy towards gluten network formation. The salt reduction gradually decreased the mixing time and consequently the warming of the dough during mixing. The resistance of the dough to extension was measured by a traction test done on a stripe of dough (Kieffer Rig). The resistance to extension (force exerted by the dough string) decreased progressively with decreasing salt while the extensibility (capability to bear the deformation) slightly increased. The impact of salt reduction on dough stickiness was very small. Only the dough containing no salt was significantly stickier than others. For dough containing salt, the stickiness of the dough was unchanged whatever the quantity of salt used (differences were not statistically different).

In conclusion, the effects of a salt reduction on dough texture properties seem moderate. Similar findings were obtained for the LPP dough in which a salt reduction of up to 30% is possible without major deviations to a full salt control. No technical limitations for salt reduced LPP doughs could be observed in test scales, but LPP containing no salt and „very low salt“ were poor in taste.

Two prototype equipments were developed and used for the baking applications within the project. A prototype vacuum mixer has been constructed by VMI; it can operate between -0.9 atm and +0.5 atm. It has been successfully used to study the impact of mixing pressure on model dough. The energy parameters during mixing can be logged as well as temperature and overall consumed energy. The specific energy input and power consumption were found to be higher in the recipes containing high amounts of salt. Results showed that salt reduction resulted in more sticky dough for extreme salt reduction. Besides, salt reduction made the dough more plastic. Vacuum mixing helped significantly to reduce dough stickiness and contributed to make the dough more plastic and therefore more adapted to severe dough sheeting. Apart from pressure, salt also had a role to play in the porosity of the dough. It was observed that addition of salt inside the recipe was responsible for increasing the porosity of the dough.

A prototype dough sheeter has been assembled jointly by PROMATEC and ONIRIS. It is equipped with sensors to measure the temperature and the thickness of the dough after sheeting. The sheeter enables to distribute a uniform layer of (encapsulated) salt, adapted to the technology of encapsulated salt in pizza dough. The pressure during mixing was also an important factor affecting the torque requirement of the tool (spiral) during mixing. Lower relative pressure values were found to increase the torque requirement at lower roller gaps (1.2 and 0.8 mm).

The effects of salt (nominal, - 25%), vegetable fat (FB1, FB4) and mixing pressure (atmospheric and -600 mbar) on mixing time and PD properties (stickiness, dough deformation) were studied.

The pressure and the type of fat being used have significantly affected the mixing time. With a decrease in pressure, the
mixing time was reduced which could be very well explained as the amount of air enclosed during mixing gets reduced. The mixing time was found to increase with the reference fat (FB1). Only the salt content was not affecting the mixing time much but, in combination with the fat content, it was showing higher values for FB1 than for the modified fat (FB4). In combination with the lower pressures and the softer FB4, the time needed for mixing was significantly lower than that for FB1.

The study indicated that the type of fat used in the recipe is a crucial parameter for various rheological properties of the dough. FB1 tended to increase the mixing time whereas the modified fat (FB4) in the recipe increased the stickiness as well as baking deformation. However, the stickiness and baking deformation were not significantly different for both the types of fat.

Salt crystal integrity is not maintained during baking. To enhance saltiness intensity, it is very important to preserve salt crystal integrity by the use of encapsulated salt within fat. A sensory study by QDA (Quantitative Descriptive Analysis) showed that the use of encapsulated salt, independent from its granulometry, added by sprinkling during laminating can enhance saltiness perception of pizza dough by 30% in comparison with pizza dough made with dry salt added during mixing.

Analytical methods for measuring the textural and structural quality characteristics (firmness, specific volume, number of cells and slice brightness), of baked LPP were applied including Texture Analyser attached with Extended Craft Knife (ECK) and Multiple Puncture Probe (MPP), VolScan and C-Cell image system. Response surface methodology (RSM) was used to evaluate the effect of the varying independent processing parameters (fat reduction, number of theoretical fat layers and final dough thickness) on the dependent variables like firmness, specific volume and number of cells, which were used as quality parameters for the baked LPP. The number of layers and the final dough thickness showed to exert a high influence on the quality of the final product. With changing these processing parameters it was possible to produce LPP with a reduced fat content (minus 30 %) with the best possible quality characteristics compared to conventional products.

Generally, LPP containing harder FB with higher SAFA contents achieved excellent baking results for conventional full fat and fat reduced LPP. A fat reduction by 30% compared to the full fat control did not lead to adverse effects in lift and specific volume using the two hardest FB. Due to the higher amount of rapeseed oil (lower SAFA content) and their melting behaviour the two softest FB were unsuitable for puff pastry production.

Extensive shelf life tests were performed for LPP with reduced salt and fat levels. Doughs were stored chilled (4 °C) or frozen (-18 °C) over a 6 week period. All doughs were tested weekly for microbiological spoilage, pH, water activity (uncooked) and texture tests. The microbiological contamination for all LPP stored at 4 °C was exceeded after 4 weeks. The maximum lift and specific volume for doughs stored at 4 °C decreased significantly over the 4 weeks period. Bacteria may adversely affect the physicochemical properties of the LPP. Alcohol (preservative) addition and freezing significantly reduced the decrease in lift and specific volume over 6 week storage. These are effective methods for extending the shelf life of PP. Salt reduction had only a low impact on the microbial spoilage of LPP since the water activity was very high for all doughs (> 0.96).

Consumer studies were carried out, in order to assess the quality of the fat and/or salt reduced LPP using control LPP (full fat/salt content) as a counterpart. The results of these consumer studies showed a high level of acceptance towards fat and salt reduced LPP.

Finally, the improved recipes for fat and salt reduced PD and LPP were used as basis for the production of sweet and savoury filled RTE meals.

WP 3 Low fat and low salt meat products
The WP3 investigated and evaluated new processes and recipes for the development of fat and salt reduced meat products. Salt reduction
Besides its application as flavour enhancer, salt has been used in food industry for preservation and to ensure longer shelf-life. Salt lowers the water activity, hence inhibiting growth and reproduction of microorganisms. Moreover, salt has a crucial function in structure formation, interacting directly with major constituents, such as meat proteins. Product texture and juiciness are major quality parameters of meat products and are closely linked to the salt content due to the salt impact on protein hydration. On the other hand, nowadays new promising technologies are available which could help developing and brining new products into the market. Such one is certainly high hydrostatic pressure processing (HPP). This processing principle is based on extremely high pressure levels (up to 6000 bar) applied on the product uniformly under water. Such high pressure is able to inactivate vegetative microorganisms. Under the high pressure other molecules, such as meat proteins, can
be affected, but not some valuable compounds (e.g. vitamins). Depending on the pressure levels and temperature during the pressurisation, different phenomena can occur. Pressure levels between 5000-6000 bars are often used for preservation purposes (mostly juices and RTE products). In case of meat high pressure leads to protein denaturation and solidification. Pressures in the range of 3000 bars often lead to protein solubilisation and hydration. Lower pressure levels of 1000 bar allow protein conditioning and gelation, leading to similar effect as presence of salt. In that sense, application of HPP process as a potential technique for development of salt reduced meat product has been investigated. On the other hand, HPP can be used to denature the protein without cooking. If one would use the “HPP-cold-cooked meat” (containing more protein and less fat) and partly replace the animal fat in the meat product, the actual result would be less fat, more protein, and acceptable appearance of protein that looks like fat.

The first part of the study focused on possibilities to reduce salt in meat products. Because of its popularity in Europe, Bologna type sausage and cooked ham have been chosen. Different salt reductions have been tried out, ranging from 0 to 100 % salt reduction and different pressure levels (1000-6000 bars) at several processing steps (e.g. before chopping and after stuffing) as well as different phosphate levels (0.06 % and 0.25 %) were examined. Moreover, the application of potassium chloride (KCl), which has similar effect on protein solubilisation as sodium chloride (NaCl) has been investigated. As a reference salt content, concentration of 1.8 % and 1.9 % were determined for sausage and cooked ham respectively.

The preliminary trials showed that salt reduction more than 30 % strongly affects the sausage quality in terms of texture. It was decided to work on the formulations having 30 % salt reduction as it is a significant reduction which is above the 25 % salt reduction needed to make a claim as “reduced in” according to the European regulation (EC) no 1924/2006 on nutrition and health claims made on foods. First obtained results showed that the reduction of phosphates in formulations for sausage and cooked ham has a negative effect on the structure and water binding properties. As the salt concentration has a strong impact on sensory and texture properties, those two parameters were in focus during evaluation of new recipes.

The results have shown that the salt content can be reduced by 30 % without significant changes in colour, texture and water binding properties of salt-reduced sausage and cooked ham, compared to reference ones. However, the taste of salt-reduced sausage and ham was perceived by sensory panel as less salty, but still acceptable. A further salt reduction by partial replacement of NaCl by the addition of KCl (0.26 %) to a final NaCl reduction of 45 % and 42 % in sausage and ham respectively, was also possible. However, the addition of higher concentration of KCl could lead to a typical bitter flavour. For the production of salt reduced cooked ham, only HPP treatment at 1000 bars after tumbling and application of pressure of 6000 bars on the final product (after cooking) were suitable.

Further, the pressure treatment enhanced the structure formation of salt reduced cooked ham. Measured colour differences showed minimal visual effects at the salt reduced cooked hams in comparison to the control. The salt reduced cooked ham had an acceptable quality although the taste was perceived as less salty but accepted by the sensory panel. The declaration with the claim “reduced in...” is possible for both products. The developments have shown the possibility to produce stable salt reduced meat products. During the development stage the project has focused on the technological aspects related to the reduced-in meat products.

Fat reduction

Fat is an important food constituent contributing to sensorial perception of food as well as interacting with other food components and determining the rheology. Oils and fats are the energy source for the human organism supporting at the same time also the mouth-feel of the food. Sensory, functional and nutritional properties of fats and oils are determined by the levels of palmitic (C16:0) and stearic (C18:0) saturated fatty acids, oleic (C18:1) monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and trans- fatty acids. In order to reduce and replace the animal fat within the meat products, olive oil (rich in oleic acid) was used. Different concentrations of fat and combinations with olive oil have been tested. The main quality parameters evaluated were water holding capacity, texture and colour. Moreover, sensory analysis has been carried out to determine the acceptability of the reduced and animal fat replaced sausage.

- Cooked sausages Bologna type

Result obtained for the colour differences showed that the difference is increasing as the fat is reduced, either in the samples where the fat was replaced by the meat fraction or replaced by olive oil. In the first case where fat was replaced by meat fraction, the product appeared redder, which was perceived positively by sensory panel. However, measured colour difference was still acceptable as it could be visible for a trained eye only. In terms of texture, newly developed products appeared not to
be significantly different from the reference one. Based on the different formulations, expected differences in fat and protein concentration were observed. Regarding the total saturated fatty acids content, logically the lowest levels were shown for the fat reduced samples. The highest content of saturated fat is shown to be at the reference sample. The most important unsaturated fatty acid in olive oil is oleic acid; hence the samples having the higher content of olive oil also had the higher content of oleic acid. This proves that by replacing the animal fat with plant-based fat, a lipid profile of the meat product could be improved. Polyunsaturated fatty acids (PUFA) have not been strongly affected by the addition of olive oil, because they are not significantly provided within the olive oil. Finally, cooked sausage with 45% fat reduction was considered as the best by sensory panel in terms of appearance, texture, flavour and smell. Also product having 6,5% of olive oil as well as the combination of 30% of fat reduction with 2% olive oil showed good lipid profiles and acceptability by the sensory panel, thus representing realistic strategies to improve the lipid fraction of cooked sausage Bologna type.

• Dry cured sausage
In order to reduce the fat content from fermented sausage by fat reduction (35%) or replacement by olive oil (10%), several approaches have been used. First olive oil has been used in three ways: olive oil as a replacer, as an emulsion with milk proteins and encapsulated in wheat starch by an extrusion process. Second, HPP treated meat as a fat replacer was employed as a novel strategy to reduce the fat content while the visual appearance is kept similar, where denatured proteins are simulating fat particles.

The addition of pure olive oil indicated oil dripping and poor binding properties of the final product. The addition of HPP treated meat together with oil showed similar result. The results indicated that emulsion was unsuitable for fat replacement in this kind of product, as the colour difference and fat oxidation were also high. A lower colour difference as well as similar oxidation levels were observed, when olive oil was used in encapsulated form. As a final conclusion, the most suitable formulations for fat reduction and replacement in dry cured sausage were: the fat reduced one containing HPP treated meat and the fat replaced by encapsulated olive oil (picture not shown). The final 35% reduced product showed good appearance and good overall acceptance by the sensory panel. However, it has to be noted, that the drying loss was higher compared to the control. This could be improved by application of HPP treated meat.

In the last part of the study, the products developed were subjected to investigation over the certain period of storage (30 days) in order to evaluate quality changes as a function of time. Salt reduced cooked ham showed satisfying texture and microbial stability. Cooked sausages, fat reduced and salt reduced, appeared to have slightly softer structure compared to the reference. Both products were microbiologically stable over the tested period of 30 days. In terms of colour, salt reduced products have had quite low differences, whereas fat reduced showed a bit higher colour differences, mostly due to fat replacement (meat replacement or olive oil addition).

It can be concluded that stable salt and fat reduced tested meat products are feasible, with minor impact on physical and sensorial properties. The selected products do not seem to change significantly over the investigated period of 30 days.

WP4 Low salt and low fat mozzarella-style cheese

The WP 4 of PLEASURE commenced with a careful assessment of the regulatory environment pertaining to (a) Mozzarella cheeses and (b) a related cheese group, frequently referred to Pizza cheeses. The distinction between the 2 cheese categories is that Mozzarella cheese is well defined as a retail product for table use as well as cooking while Pizza cheeses are a more generic group aimed at meeting certain functional criteria e.g. pizza topping in food service applications. The US Code of Federal Regulations (2008) enabled 2 Standards of Identity (based on moisture, and fat in dry matter contents) to be attributed to each of the following 2 types of cheeses:

1. Mozzarella cheese produced for consumption as a retail product and for food preparation in domestic and food service situations
2. Mozzarella-style pizza cheese produced primarily for food service applications driven by competitive practices in commercial pizza preparation and ‘fast-food’ retailing

The consequences of factoring fat and salt reductions of the order of 30% were then factored into the above cheese so that the ramifications to their Standards of Identity could be carefully assessed in theoretical terms. Subsequently, a method for the development of a reduced-fat, reduced-salt Mozzarella-style cheese was required, one that would allow for scope for modifications to the resultant cheese. Trials indicated the difficulty in attaining compositional targets
owing to varying degrees of fat and salt for cheeses of different fat content. Once the optimisation of methodology was complete, production of experimental cheeses could commence. The first task of the cheese development was the investigation of the interactive effects of reducing fat and salt content. An experimental matrix consisting of four cheeses were investigated; full-fat / full-salt (FFFS), full-fat / reduced-salt (FFRS), reduced-fat / full salt (RFFS) and reduced-fat / reduced-salt (RFRS). Furthermore, two addition variations of the reduced-fat cheeses were made investigating the effects of reducing the calcium-induced casein-crosslinking through technological adaptation of the make procedure. Cheeses were analysed for composition, biochemical, textural and functional attributes throughout ripening, in addition to a sensory study undertaken of raw and cooked Mozzarella at 15 and 35 days. Results showed the magnitude of the effects of fat and salt reduction both individually and interactively. Overall, the effect of fat reduction had a much more significant effect on cheese quality than salt content. Reduced-fat cheese had significantly poorer quality attributes in terms of textural, flavour and cooking properties.

In order to overcome these deficits two further techniques were employed, namely, the incorporation of enzyme modified cheese (EMC) paste into the cheese to address the flavour shortfall, and the elevated level of protein hydrolysis in the cheese mitigated through increased levels of rennet retention. These two approaches necessitated the development of further make procedure modifications.

For retaining added EMC paste the make procedure of Mozzarella style cheese was adapted. This adaptation allowed for EMC paste to be retained and distributed evenly through the cheese matrix. During this set of experiments, 3 levels of EMC inclusion were investigated; (0%, 1.25% and 2.5%). Upon cooking this EMC releases volatile compounds contributing to an increased perception of fat aroma and flavour from the reduced-fat, reduced-salt cheese, increasing its desirability. The EMC also had an unexpected impact on cheese functionality, with respect to cheese meltability which was significantly increased with increasing EMC content. The results showed that 1.25% w/w was the optimum level of EMC content for flavour enhancement as above this, EMC was deemed to be ‘overpowering’.

Following this, cheese trials involving increased levels of rennet addition were undertaken. EMC was added at a rate of 1.25% w/w and a range of rennet levels were employed from 0.14% to 0.36% w/w. The results showed a significant effect of rennet addition on heat-induced flow, cheese texture and stretchability, while retaining the improved flavour profile achieved in the previous set of trials. The cheese developed displayed superior melting properties to both the control RFRS and FFFS cheeses while possessing a flavour profile similar to that of FFFS cheese when cooked.

The final aspect of the development of this cheese was to ensure its microbial safety. This was investigated through a challenge test involving Listeria Spp. The test investigated the survival and growth of Listeria in cheese at three timepoints over a three week period in which the cheese would typically be consumed. Cheese was subjected to normal and abusive storage conditions (4 and 22 °C respectively). The results showed that the Mozzarella cheese developed did not support the growth of Listeria under the conditions investigated over the three week period and that abusive storage conditions were not a significant factor in the growth of Listeria in this cheese. This suggests that there is little call for increased concern regarding consumer safety in relation to this cheese.

In conclusion, the project objectives were all achieved; a reduced-fat, reduced-salt Mozzarella-style cheese was successfully developed that rivalled the quality of a full-fat, full-salt control in terms of functionality, flavour and textural properties and did not support the growth of pathogenic micro-organisms. Novel processing approaches for the development of RFRS Mozzarella has been successful established and implemented and a more in-depth knowledge of the interactions of the components of the cheese matrix has been gained.

WP5 Sugar, salt, saturated and trans fat reduced fruit & vegetable preparations for the use in RTE meals
As sauces like mayonnaise, carbonara style sauce as well as fruit and vegetable sauces (e.g. tomato sauce) are frequently used in ready to eat meals, WP5 aimed at improving their nutritional profile. For fruit and vegetable products, the major objective addressed the reduction of the main sugar components glucose, sucrose and fructose. The approach was to develop novel innovative processes and minimize the use of replacers and artificial ingredients. In addition a further challenge was addressed by the development of processes with mild conditions to keep valuable components present in fruit and vegetables. As further important objective, a minimum sugar reduction of 30% has to be reached, enabling the labeling with claims like
“sugar reduced” according to EU regulation 1922/2006. For sauces with a high fat content (carbonara style and mayonnaise) WP5 aimed on the development of an innovative technology for the production of fat reduced emulsions with a texture comparable to emulsions with the original high fat content.

Development of enzymatic and fermentative sugar reduced fruit & vegetable preparations
For the enzymatic process, different enzymes were tested according to their performance in a model matrix. In addition, analytical protocols for the sugar quantification in the samples were established. Based on these results a lab scale process was set up and important parameters were identified. Therefore, different setups were tested and the most suitable was identified and adapted first to apple puree as an economic and readily available model puree. In addition, a process control unit for monitoring the reduction process was successfully established. The process was up scaled to pilot plant and adapted to other purees like strawberry, peach but also highly viscose tomato paste. In all purees the requirement of an almost 30% reduction in total sugar could be achieved. Even sugar reduction rates exceeding 30% could be reached, depending on the individual sugar composition of each puree.

In addition to the enzymatic process also a fermentative sugar reduction process was developed based on the idea of converting the high caloric sugars like glucose, sucrose and fructose to the low caloric sweetener erythritol. Initially, within a literature search potentially erythritol producing strains were identified and ordered. These strains were screened for their ability to form erythritol on different model matrices. Stains meeting these requirements were further characterized. In addition, an easy sample preparation method was established to control the process and the fermentation by-products. The most promising strain of the screening was adapted to the viscose fruit matrix of apple puree and the process was further optimized, especially regarding the setup, which could be up scaled from first trials at a lab scale volume. Within further research work, the process developed was successfully transferred to other fruit and vegetable purees. The overall results clearly demonstrated the conversion of sugars to erythritol and the achievement of sugar reduction rates exceeding 30%.

For the combination of both processes different approaches were considered. The final process combination includes also a mild heat treatment to guarantee the safety of the produced products. In summary, the development of enzymatic and fermentative sugar reduced fruit & vegetable preparations was successfully completed and the processes developed are patent pending.

Development of fat, salt and sugar reduced vegetable sauces for RTE meals
This work describes the use of high pressure homogenization (HPH) as an important alternative to produce fat reduced emulsions with particular emphasis on keeping desirable texture. Two different model sauce systems were used, mayonnaise-like system and cream-like system. Keeping viscosity values similar to traditional and commercial full-fat mayonnaises, High Pressure Homogenization technology was able to reduce 35% of fat with any addition of thickener agents whatsoever. A 75% and a 98% fat reduction was achieved by adding inulin to the already treated reduced fat emulsions, producing similar viscosity values to the commercial sauce. In the case of carbonara sauce, addition of inulin was also needed to produce similar viscosity values to the commercial sauce for reducing the fat up to 1.5% content.

The influence of the process parameters was also studied, mainly focusing on the texture of two different sauce formulations with an important reduction of fat. Two different model sauce systems were used: mayonnaise and carbonara sauce. Based on the previous results, different pressure treatments were used. These treatments were therefore used at different formulations from a reduced fat sauce with 52% oil content up to 1.5% oil. Latter formulation was combined with the presence of inulin. At the final stage of the project, all the acquired knowledge was used to design three different recipes chosen as the best formulations to achieve optimum rheological properties, sensory properties and emulsion stability throughout the time. HPH technology was able to produce low-fat and low-salt sauces with similar texture as full-fat commercial sauces. Adding inulin to the already treated 98% reduced-fat emulsions produced higher viscosity values as the commercial sauce. A salt reduction of 50% showed same texture than the traditional sauces. Therefore, by combining pressure treatment, inulin concentration and salt concentration, it was possible to produce a full range of reduced-in sauces.

Safety evaluation of the developed products
Regarding to safety aspects, mayonnaise-like sauce system with fat reduction, without thickeners and chemical preservatives, treated by HPH and stored at room temperature showed a shelf life of at least 90 days (physical stability was also achieved). Safety results showed that HPH can be used as a preservation technology.

All the results (for mayonnaise and carbonara sauce) clearly conclude that it is possible to obtain sauces with a fat content...
down to 1.5% and open a new window for the production of healthy sauces without missing the original sensory properties. Furthermore, the microbial stability of the sugar reduced fruit and vegetable components that were produced using the newly developed enzymatic and fermentative process was assessed, demonstrating good results and stable products. In addition, a natural bio preservation process for the sugar reduced fruit and vegetable components was investigated. This bio preservation process supports a minimal processing of the purees and therefore delivers an added value to the developed sugar reduction processes.

WP 6 Assimilation of RTE-meals based on the components developed in WP2 to 5

WP 6 aimed at developing optimized solution of assembled food reduced in salt, sugar and lipids. This research was based on the single ingredients developed in the previous work packages: pizza dough and laminated puffing pastry (LPP dough) in WP2, cheese in WP3, meat in WP4 and sauces in WP5.

Specific challenges regarding the reduction of tastant (salt and sugar in particular) can be adjusted using different strategies:
- by reducing the amount of tastant in each ingredient used in the assembled food
- by modifying the mass ratio of each ingredient of the assembled food
- by acting on the two above mentioned actions

Therefore, the field of possibilities is very broad, in particular for a complex assembled food like a pizza containing dough, tomato sauce, ham and cheese. However, the mass ratio of each ingredient is supposed to be spread over a given interval. Also, the reduction of tastant in a single food ingredient has some limits. In the case of cheese for example, a certain amount of salt is needed to keep the cheese structure. The same remark applies to meat; a certain amount of salt is needed to ensure a certain water holding capacity. Salt is also important for the dough as it interacts with the gluten network rheology. Most of the research has been done on the pizza system, as it is the emblematic food of PLEASURE project. Modifying the salt content of each ingredient without changing the total salt content of pizza has been done using mixture experimental design, to demonstrate its impact on sensory properties, and to determine the formulation with sensory properties. Sensory perception has been evaluated by Quantitative Descriptive Analysis, and compared to the reference product. For the present case, the pizza was made of dough, ham, cheese and sauce in constant proportions. Results were analyzed by two complementary statistical methodologies: multivariate analysis and predictive regression model. The distribution of salt between ingredients affects taste and texture perception.

The pizza system was composed of pizza dough (45%), tomato sauce (15%) cooked ham (20%) and cheese (20%). The first reduction strategy was based on the optimisation of salt, sugar and fat reduction of each ingredient, pizza dough, tomato sauce, ham and cheese constituting the ready-to-eat product. The second strategy was focused on the reduction of 30% of salt content of pizza without altering the organoleptic properties of the product. According to literature, an inhomogenous spatial distribution of salt can be an efficient way to increase saltiness perception in single component food (Meiselman et al., 1973; Busch et al., 2009; Noort et al., 2010; Noort et al., 2012). It was possible to adapt this strategy to a multi-component ready-to-eat food as pizza reduced of 30% of salt.

To modify the salt distribution between ingredients, while preserving their proportions, it was necessary to use ingredients with different salt content with mixture experimental design. A mixture experimental design was developed on salt-reduced pizza (~30%) based on simplex methods, with 10 points and 1 central point in triplicate. For each ingredient SALI, SUGI, SATI and SSI indexes were calculated. For the multi-component food, SALI, SUGI, SATI and SSI indexes were calculated from weighted average of each index from each ingredient by the proportion of ingredient within the multi-component food.

The main results obtained showed that modification of salt location between ingredients affects different sensory properties, such as taste and texture perception and, more particularly, “salty”, “acid”, “elasticity” and “pasty” attributes according to the QDA results. A mixture experimental design enables predictive regression models to be developed to estimate the values of each attribute separately for various products. Regarding experimental pizza mixture formulations, the “salty” perception increased when salt is preferentially located within ham; the “acid” perception decreased when salt is preferentially located within tomato sauce; the “elasticity” perception increased when salt is preferentially located within cheese; the “pasty”
perception increased when salt is preferentially located within dough. The salt concentration of each ingredient will thus induce a different effect according to the attribute considered. However, multi-response predictive regression based on an analysis of mixture experimental design results demonstrated that it is possible to reduce the salt content of pizza by 30% without altering its organoleptic properties by varying the relative proportion of salt provided by each ingredient. This mixture is composed of 20% of salt from cooked ham, 47.5% from mozzarella-style cheese, 0% from dough and 32.5% from tomato sauce. Salt should thus be located preferentially within mozzarella-style cheese and tomato sauce whereas it can be extensively reduced in dough. Multivariate analysis completed the relevance of this salt-reduced pizza as the closest to the reference.

These results underline the significance of modulating salt distribution between each ingredient in the perception of multi-component foods, and the complexity of perception mechanisms. Results were obtained using QDA analysis. Although the use of this methodology remains a standard in the sensory analysis field to describe modifications of the sensory profile of products, it is also considered a static overall evaluation. Modifying salt location between ingredients to reduce the salt content of pizza is based on the generation of a more intensive sensory contrast between ingredients and a more pulsatile delivery of salt during mastication. To go further, it will be interesting to assess the impact of this new salt reduction strategy using dynamic sensory methodologies to determine whether the kinetics of perception vary according to the location of salt in multi-component food.

Regarding the puff pastry filled with meat and the puff pastry filled with apple puree, one strategy was developed for each. For puff pastry filled with meat the strategy is based on the optimization of salt, sugar and fat reduction of each ingredient, puffing pastry (60%) and sausages (40%) while for puffing pastry filled with apple puree, the strategy is based on the optimization of salt, sugar and fat reduction of each ingredient, puffing pastry (65%) and apple puree (35%).

The results concerning the optimization of the artificial mouth prototype (AMADEUS-Automated Mastication for Artificial Destructuration and Extensive Understanding of Stimuli) showed that the artificial mouth was able to efficiently mimic human food oral processing of assembled food such as pizza and puffing pastries regarding the salt release and the particle size distribution of the chewed pizza.

Thanks to the optimization performed in the artificial mouth: Setting parameters regarding the frequency of chewing, saliva flow rates and teeth geometry, the shape of the salt release kinetic curve obtained while pizza chewing was similar to the average curve obtained by in vivo chewing pizza.

These results arise a new light in the oral processing study of salt reduced food products as by using this in vitro masticator it would be possible (i) to avoid in vivo techniques which are generally time consuming and also (i) preventing the variation in the in vivo data results due to the anatomical and physiological differences among individuals, and therefore (iii) making easier to study differences among food products.

PLEASURE developments were successfully disseminated and validated through a wide range of dissemination and demonstration activities, special focus on this aspects being set during the course of the project. In the last stage of the project also an international consumer survey comprising 5 EU countries (Romania, Spain, Germany, Ireland and France) was performed successfully identifying the consumer’s sensory preferences / acceptance in relation to the PLEASURE reduced-in foods (reduced in fat, salt and sugar) vs the conventional ones. The results obtained showed that the reduced-in foods developed in PLEASURE, are well perceived and accepted by the consumers, overall having similar sensory properties with the conventional ones. In many cases the reduced-in food products were not identified at all as containing less fat, salt or sugar, quite often the sensorial perception and the acceptability of these components being rated even higher than the conventional products, making thus PLEASURE project successful.

Potential Impact:
In recent years the demand for and consumption of convenience foods has greatly increased. Due to a higher prevalence of mothers working outside the home and changes in societal norms, the consumption of these foods is at an all-time high.
Health problems associated with the overconsumption of these foods, coupled with a decrease in physical activity have increased to epidemic levels. The prevalence of overweight and obesity in the developed world as well as other diet-related health issues, e.g. hypertension, diabetes, coronary heart disease can be attributed to a more sedentary lifestyle, along with an increasing market for convenience foods that are high in fat, salt and sugar. For example in Germany, pizza consumption has increased with more than 60% in the last 10 years (Deutsche Tiefkühlinstitut, 2013). Beside this, the consumer expectations survey performed in the initial stage of the project showed that there is also a global lack of trust of the European consumer regarding the nutrition claim “reduced in”. The percentage of reduction corresponding to this claim was unknown by most consumers. Therefore PLEASUE has designed indexes proposing numbers (ranging from 1 for reference food to 0 for the product “free of”) instead of statements; these indexes could be considered in the future as replacers of some nutrition statements. Further, the project put to the fore the non-uniformity at European scale of the “reference” values (i.e. salt content, sugar content) used, for example, to establish the nutrition labeling “reduced in” or “low in”, and proposed to use a same value for all European countries. This will be challenging but should result in an overall reduction of the salt, fat and sugar consumption in Europe.

It is widely acknowledged that certain socio-economic groups, such as those at the lower end of the socio-economic scale who are very reliant on fast-food such as pizza; students at college who are at a vulnerable stage in terms of dietary choices and food intake, are more likely to choose convenience foods, due to financial and social reasons, and are, hence, at an increased risk of developing diet associated health problems. At the other end of the scale are groups such as ‘lifestyle consumers’ who demand both quality, in terms of health and wellness, as well as convenience from food. The demands of these groups could be met through the PLEASURE development, and possibly bridge the gap between the two extremes of the range of convenience food consumers.

PLEASURE is an ambitious project that has a major impact on developing and manufacturing of traditional and processed food from different European countries, pizza representing the ambassador of the project. Besides this, the four food categories considered in PLEASURE (bakery, cheese, meat, vegetable/fruit sauce) are among the major contributors to the salt, fat and sugar in Europe.

Puff pastry is a high-fat bakery product with fat playing a key role, both, during the production process and in the final pastry. The fat cannot be replaced completely without adversely affecting the product quality. Generally, fat is essential as flavour carrier and gives the final product its specific characteristics, such as a good structure, texture and mouthfeel. Salt is important as a flavour enhancer, for a well-developed dough structure and to control the water activity in the dough. PLEASURE showed that it is possible to reduce the salt level of PD and LPP by 25% and the fat level by 30% obtaining products with similar characteristics like reference products. These reductions are possible with technological changes only. Salt reduction is possible by sprinkling encapsulated salt during laminating process on the dough. This can enhance saltiness perception of PD by 30%. Salt encapsulated which was at “low melting point” (i.e. 60°C) resulted in a better protection of the salt grains against dissolution. The encapsulated salt could not be preserved more than 1 to 2 days, and finally was dissolved in the dough. A vacuum mixer has been developed by partner VMI and has been used as a support to reduce the salt content in the PD. The high reduction of salt tends to make the dough stickier. Mixing the dough under vacuum reduces the access to oxygen during mixing and permits to obtain a less sticky dough. Also, vacuum mixing reduces dough porosity. It tends also to make the dough more plastic; these properties making the dough less springy and facilitate the sheeting (less springiness). Further PLEASURE demonstrated that a fat reduction of 30% in LPP is possible by reducing the number of fat layers and by varying the final dough thickness.

Thus the bakery products developed within the project enable the labelling with claims like “fat reduced” and/or “salt reduced” according to EC regulation no 1924/2006. In case of the fat reduction in LPP no additives or fat replacer were used what even can lead to a “clean” labelling.

In the meat products (Cooked ham, bologna type sausages and dry cured sausages) salt as well as fat are applied for sensorial reasons but also due to their structural impact on texture, water activity and water holding capacity. In general the project results significantly contribute towards the development of low fat and low salt meat products and provide a basis for uptake of such products into industrial production. Major interactions between product formulation, processing conditions and quality parameters have been established. The sensorial test performed during the project have highlighted the general acceptability of the products developed, but it remains questionable if and to which extent consumers are willing to pay more for healthier
meat products. Possible extra costs mainly resulting from additional ingredients and processing steps, in particular such as
pressure applications, can cause significant efforts. The project results have shown that by a combination of HPP and salt
replacers a sodium reduction of up to 45 % can be achieved. The use of HPP has allowed a modification of protein structure
and enhanced water binding, partially replaying the function of salt. Pressure levels in a range of 100 MPa / 1.000 bar have
been required to achieve that effect. To achieve a sufficient level of saltiness salt replacing ions can be added. The use of high
pressure for structure modification of protein based food matrices has a high potential for commercial exploitation. In
comparison to HPP industrial applications so far, a lower pressure level is required, but however is still resulting in some
investment and as well as extra processing efforts.

Besides sodium also a reduction of fat content in cooked and dry cured sausages was attempted upon. The results have
shown that by use of meat as well as olive oil as fat replacer, products with a high consumer acceptance can be achieved. Fat
reduced (45 % reduction) samples have received the consumer preference for Bologna type sausages. The project results can
be transferred into industrial practice within short to medium time frame, as conventional processing techniques and
equipment can be applied. From a cost perspective the use of olive oil can result in a slightly price increase for total
processing costs. Considering the consumer desire for low fat products the costs can be covered by a premium sales price. The
results can therefore have a high impact. Also for dry cured sausages olive oil was used as a fat replacer either pure, as an
emulsion or encapsulated in wheat starch. In addition HPP was applied to change the structure and visual appearance of lean
meat and allow its use as a fat replacer. An optimum combination was found using HPP treated lean meat in combination with
encapsulated olive oil. The formulation included replacement of 20 % of the meat by HPP treated meat. As HPP systems within
the pressure levels used in the present case, are commercially available and toll processing services are offered by a number
of toll processing entities, the results can be quickly transferred into industrial practice.

In summary, the project results will impact on meat industry´s opportunities to manufacture low fat and low sodium products
with high consumer acceptance. The basic interactions of formulation, processing steps as well as product characteristics have
been elaborated and will be available for potential users. In addition, the use of HPP as a structure modification technique has
shown to enhance functional properties of meat and to allow to partially replacing the water holding function of salt and fat.
That will broaden the application range of HPP equipment and trigger further market potential for equipment manufacturers.
In particular, the use of lower pressure levels than the ones currently applied will result in further process and equipment
design and development of units with lower investment costs.

The fundamental approaches adapted in the development of the reduced-fat, reduced-salt Mozzarella-style cheese for this
project have resulted in the advancement in technological adaptations of cheese making in order to make the necessary
improvements to reduced-fat, reduced-salt cheese. The scope of these adaptations is huge in the sense that they can be
readily applied by industry and are applicable to a range of cheeses. Therefor the research has been much more rewarding in
terms of information gleaned, rather than strictly in relation to changes in cheese behaviour brought about by fat and salt
reduction.

The cheese developed through this project offers a healthier alternative to commercially available low-moisture part-skim
Mozzarella and pizza cheeses. The PLEASURE project attempts to counteract some of the reputational damage done to cheese
products in recent years through the release of poor quality fat-reduced cheeses, which has induced a cautious approach from
consumers. This has been achieved through sensory characterization as both a table cheese and also as an ingredient in the
formulation of composite foods, such as pizza. The cheese is approximately 50% lower in fat and 30% lower in salt content
than commercially available versions, while having increased protein content and from this point of view the cheese offers the
opportunity to be marketed as a more health conscious dairy food. The increased satiety factor, associated with the high
protein content, could potentially appeal to dieters and the health conscious, while the reduced sodium content could appeal
to those suffering from hypertension, as a high sodium intake is widely associated with increased blood pressure. This could
prove a useful tool for those suffering from overweight or obesity that struggle to control their weight through diet as it offers
the opportunity to continue the consumption of foods that would typically be considered high in fat but at a reduced fat, salt
and caloric intake.

Fruits and vegetables, due to their high levels of vitamins, minerals and secondary plant products, are usually part of a healthy
diet. However, fruits are also high in sugar. Consumption of large amounts of sugar is associated with caries and high energy
content, contributing to the development of obesity. This may especially be linked to fruit and vegetable purees being often
consumed as part of ready to eat meals. Therefore, new technologies have to be developed keeping the natural content of healthy fruit and vegetable ingredient but significantly reducing the sugar content of these products. Such processes for sugar reduction were successfully developed within PLEASURE and thus provide a great tool for the production of sugar reduced fruit and vegetable purees. In addition, the processes developed are easy to implement in existing fruit production processes at low costs. The successful sugar reduction by almost 30% opens the possibility for labelling the resulting products with claims like “sugar reduced…” opening a competitive advantage for European fruit processors.

Fat in sauces, and in general in foods, is a very desirable product as it makes a major contribution to appearance, texture, mouthfeel and flavour. This is partly because life-long eating patterns are resistant to change, thereby, low-fat or reduced-fat foods are less desirable because they have poor organoleptic qualities. This fact makes the development of reduced-fat products with the same quality attributes as the original full-fat products crucial for the food industry. The impact of the sauces with a lower salt, fat and sugar content was achieved by developing new ways of food manufacturing and providing model recipes for two types of sauces with optimal products characteristics in terms of “reduced in…” as well as optimized sensory properties (general taste, texture, sweetness and saltiness perception, mouth feeling…) which was validated during consumer surveys. These achievements will also permit the development of food with nutrition claims and translate the expectations and preferences of European consumers into new food products.

The work being carried out during PLEASURE project regarding the assembled food is quite unique as up to now most of the research work available on salt or sugar reduction was done on liquid foods and emulsions. To our knowledge, it is the first time that the case of the pizza has been treated.

The potential impact of PLEASURE is very broad due to the fact that pizza is one of the most consumed RTE foods in Europe. The strategy that has been set within the project, allowed a reduction of salt by 30% while the overall saltiness perception was even higher than in the reference food (not reduced in salt). The use of encapsulated salt, embedded in the dough has been proven to be a very useful approach for reducing the salt content. The modulation of the saltiness in the dough was very efficient in reducing the overall saltiness perception. The overall recommendation is that the salt reduction in food ingredients which are rich in water is more impacting the saltiness perception. Further the impact of the project on the technique of mixing and dough sheeting has been also very useful, helping in reducing the salt content in pizza dough to a very large extent.

By using encapsulated salt in the dough and meat reduced in salt, the results obtained on meat filled laminated puffing pastry, showed an acceptable salt perception comparable to the control product. Further, regarding the sweet filled laminated puffing pastry, when dough containing amyloglucosidase (and without sugar at all) and apple sauce reduced-in sugar were used, similar sweetness with the conventional products was registered.

PLEASURE outcomes gathered the scientific bricks in order to permit the development of optimized strategies of salt, sugar and lipids reduction in particular in the case of assembled solid foods, namely RTE meals. Care has been taken to have no industry partner working directly in the RTE sector, especially in the pizza sector, so that PLEASURE is having all freedom to disseminate the results. Therefore, the results are freely available, ensuring thus a high impact to the European food industry for the benefit of the European consumers.

List of Websites:
For more information about PLEASURE please visit http://www.pleasure-fp7.com/

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