The TeRiFiQ project: Combining technologies to achieve significant binary reductions in sodium, fat and sugar content in everyday foods whilst optimising their nutritional quality

Short running head: The TeRiFiQ project

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Abstract

Most developed countries are confronted with rising rates of diseases related to unhealthy eating habits, in particular, an excessive consumption of salt, saturated fat and free sugars. However, saturated fat, sugars and salt in food influence not only its nutritional qualities but also its sensory properties, safety (*e.g.* shelf-life) and affordability. The main challenge is to formulate healthier foods which are acceptable to consumers. In this context, the overall objective of *TeRiFiQ* was to achieve significant binary reductions in the salt-fat and sugar-fat contents of frequently consumed food products around Europe, whilst at the same time ensuring the products' nutritional and sensorial qualities, safety and affordability for both industry and consumers were not compromised. *TeRiFiQ* addressed four major food categories: cheeses, processed meat, bakery and sauce products. Different strategies adapted to each food category were used to significantly reduce the target ingredients. Significant reductions in the salt-fat and fat-sugar contents of a number of cheese, processed meat, bakery and sauce products were achieved and these changes were found to be acceptable to consumers. The most promising reformulated food products were developed at the industrial scale.

Keywords:

Food, fat, sugar, sodium, perception, consumer

Introduction

Most developed countries are confronted with rising rate of diseases due to unhealthy eating habits, particularly the excessive consumption of salt, fat (in particular saturated fat) and free sugars (Campbell *et al.* 2011; EFSA 2010; EFSA 2011). Healthcare costs could be reduced and health of people around the world improved if people significantly reduced the amount of salt, saturated fat and sugars in their everyday diet. Dairy, bakery, meat and ready-to-eat products are significant contributors to intake of these nutrients and public health organisations typically provide specific recommendations about limiting certain types of these foods (Dietary Guideline Advisory Committee 2010, WHO 2007).

The salt, saturated fat and sugars contents of foods influence their structure, safety, and nutritional quality. These ingredients are also linked to multiple sensory characteristics of a food including its texture, flavour and mouthfeel, which have a large impact on food acceptability and therefore on consumer preferences. Consequently, reducing or substituting the salt, saturated fat and sugars content of a food will affect many of its properties and strategies need to be tailored to each particular product to ensure that its desirable properties remain and the reformulated food is acceptable to the consumer.

In this context, the overall objective of *TeRiFiQ* (Technologies to achieve significant binary reductions in sodium, fat and sugar content in everyday foods whilst optimising their nutritional quality; www.terifiq.fr), a €3 million multidisciplinary project funded by the European Commission under Framework Programme 7, was to achieve significant binary reductions in sodium-fat and fat-sugar contents of frequently consumed food products around Europe, whilst ensuring their nutritional and sensorial qualities, safety and affordability for both industry and consumers were maintained in order to support wide adoption of the project technology at European scale. *TeRiFiQ* addressed the four major food categories responsible for sodium, fat and/or free sugars intake: cheeses, processed meat, bakery products and sauces.

TeRiFiQ focused on binary reductions in sodium-(saturated) fat and sugars-(saturated) fat, as far as possible, as these components interact at the physicochemical and sensory levels. In addition to the technological development of reformulated foods, studies were conducted to improve the understanding of factors that influence consumer perception and consumer acceptance. This included temporal flavour release and temporal perception studies in relation to food matrix composition. Moreover, a cognitive approach, consisting mainly of the study of cross-modal taste-aroma interactions, was carried out to explore whether the addition of aromas could compensate for reductions in salt, sugars and/or saturated fat. The findings were transferred into the new food processes.

The project started in January 2012 and ended in December 2015. Its organisation is presented in Figure 1. The first three years were dedicated to the development of the reformulated products in the laboratory.

In the fourth year, the reformulated products were produced at an industrial scale and evaluated by the consumer in real-life conditions. The SME partners provided support throughout. For each food product, reductions in the amount of sodium, fat and sugars contents, the strategies used to achieve this, and consumer acceptability of the reformulated products are summarised in Table 1.

Reducing salt and saturated fat in dairy products

Salt (sodium chloride) has many important functional roles in cheese (Guinee 2004; Guinee & O'Kennedy 2007). *TeRiFiQ* examined the effects of salt reduction in three cheese types (soft, semi-hard and hard cheeses) on maturation processes and flavour quality. Solutions to correct the consequences of a salt decrease (*e.g*. impact on flavour) in each cheese category were proposed in order to maintain the acceptability of the products.

The primary role of salt in cheese is to regulate fermentation which drives the ripening process (lipolysis, proteolysis, lactates fermentations, opening *etc*.) and, as a consequence, influences the quality of the cheese (*i.e.* its texture, taste and aroma). The successive fermentations performed by the lactic acid bacteria starters and then by the ripening microflora are controlled by salt, which affects the survival of bacterial cells as well as the activity of the enzymes that are in direct contact with the cheese micro-environment. Thus, the level of salt can affect both proteolysis and lipolysis, which are the main biochemical events that determine the cheese's texture and flavour. Higher rates of proteolysis was confirmed in cheeses with lower levels of salt but the results obtained in commercial low salt (-30%) Trappist (semi-hard cheese), Emmental, Brie and Raclette showed a lower effect on lipolysis than predicted. On the other hand, the lipolysis was higher in low salt (-30%) Brie cheese.

The salt reduction (-30%) in semi-hard cheese (Raclette and Trappist) and soft cheese with moulds (Brie) had minimal effects on texture, taste, and aromas and thus did not modify the overall sensory quality and acceptability. However, in winter, butyric acid fermentation in low salt Trappist cheese was found to result in flavour defects, but this was corrected with the addition of egg lysozyme to the milk. In Boû d'Fagne cheese (soft cheese with smear), the salt reduction led to the unwanted presence of white moulds (*Penicilium camembertii*) and no corrective solution was found. In addition, the simultaneous reduction of salt and saturated fatty acids (and corresponding increase in unsaturated fatty acids by 8%) was tested in Brie cheese and this also showed only a small impact on its sensory and physicochemical properties. Thus, it is possible to make Brie-type cheese with low salt content (-30%) and modified fat composition with acceptable sensory and nutritional qualities.

Another promising way to lower the salt and fat content of dairy products while maintaining consumer acceptance is through the addition of aromas. Aroma and taste are integrated at the central level (in the

brain) and the addition of aromas can be used to compensate for lower taste quality (Salles 2006; Small & Prescott 2005). In experimental dairy products, the sardine aroma (a salt associated aroma) was shown to significantly increase the perception of salty taste in most products and the butter aroma (a fat associated aroma) enhanced the perception of fat content to varying degrees depending on the product type (Syarifuddin *et al.* 2016). This flavour-enhancing strategy was tested on a real semi-hard cheese (Trappist, Orval) with reduced salt content (-30%) (Syarifuddin 2015). With this cheese, the sardine aroma was found to enhance the perception of salty taste but the enhancement of fat content perception was only achieved by mixing the sardine and butter aromas. Thus, aroma addition alone or in combination with other strategies can assist the dairy industry when reformulating lower-salt and lower-fat foods while maintaining consumer acceptability.

Reducing salt and saturated (and overall) fat in dry meat products

In dry-fermented sausages, salt ensures microbiological safety by decreasing water activity (*i.e.* water in food which is not bound to food molecules and therefore supports the growth of bacteria, yeast and fungi), as well as influencing the drying process by drawing water from the product. Salt also affects biochemical reactions such as proteolysis, lipolysis, oxidation and fermentation. Combined salt and fat reductions in dry-fermented sausages were found to strongly impact on physicochemical characteristics, leading to more proteolysis, and less lipolysis and oxidation (Safa *et al.* 2015). Combined partial substitutions of animal fat and sodium chloride with vegetable oil and potassium chloride led to globally acceptable levels of water loss and water activity and similar rates of proteolysis, lipolysis and lipid oxidation, but less protein oxidation (Safa *et al.* 2016). Thus, this research confirmed that healthier dry sausages can be manufactured with no adverse effect on end-product physicochemical and biochemical properties.

However, reducing the amount of salt and fat added during dry-fermented sausage manufacture resulted in sensory changes that lowered consumer acceptability (Safa 2016; Safa *et al.* 2015). Study of the key aroma compounds showed that flavourings added during the process (mainly garlic) contributed to about 33% of the perceived aromatic intensity. Adding more aromatics was found to not only enhance aroma acceptability but also activate fermentation processes (mainly black pepper) that improved texture acceptability. Further research found that the reduced perception of the saltiness of the lower salt dry-fermented sausage, caused by lowering the sodium chloride content, was fully restored by replacing sodium with potassium and, although the low fat dry-fermented sausages were perceived as less soft and more firm, this was not considered unpleasant by consumers because of an increased perception of 'meaty flavour'. Also, the addition of fatty-aromas was found to enhance the perceived 'fatty flavour' of the low fat dry-fermented sausages. Overall, the research led to a 70% and 35% reduction in saturated

fatty acids and salt respectively in dry-fermented sausages, and a 60% saturated fatty acid reduction and 40% sodium reduction in chorizo. This indicates that the salt and saturated fat content of dry-fermented sausages can be significantly reduced using combinations of strategies with limited adverse effects on colour, textural properties and consumer acceptability.

Reducing salt and fat in cooked meat products

Cooked sausages mostly contain lean muscle, salt, fat and binders. The technological function of salt is mainly to improve protein and water binding (Desmond 2007) and therefore reduce water activity. It affects the macro- and micro-structure of the sausage and influences the physicochemical and sensory characteristics. Different strategies to reduce overall fat and salt contents of cooked sausages were explored. Concerning fat reduction, the use of sunflower oil emulsion to replace pork fat was found to result in an off-taste, which was not acceptable to consumers. Another alternative to reduce fat content in cooked sausages was to use lean meat, low in fat, instead of the fatty pork meat currently used; however, this has implications for affordability as lean meat is more costly. Reducing the salt content of the sausage batters was found to lead to increase overall cooking loss (water, proteins) and to a softer texture, due to weaker binding of the mixture. The use of pre-rigor meat, which has better binding properties than post-rigor meat due to its higher pH level, is a promising method to compensate for the reduced binding in lower salt sausages. Consumer acceptance of sausages with a combined 20% salt reduction and 24% fat reduction was similar to a standard sausage. However, when the consumers were informed about these reductions, the liking of the reformulated sausages was significantly reduced in line with a body of psychological research showing that expectations about a food impacts on the perception of flavour and pleasantness. To increase the acceptability of low-salt sausage, the effect of partially replacing sodium chloride with potassium chloride was explored. This approach resulted in only small differences in perceived texture and saltiness between the low salt sausage and the non-reformulated product, which minor technological adjustments in the production process are likely to resolve. At the industrial level, it was possible to substitute 20-30% of the sodium with potassium and decrease the total animal fat content by 25% without influencing the perceived sensory properties of the cooked sausages.

Reducing salt, sugars and fat in sauces

To reduce the saturated and overall fat, salt and sugars contents in sauces for ready-prepared sauces, multiple water-in-oil-in-water (w1/o/w2) emulsions were developed (Trif *et al.* 2016). Multiple w1/o/w2 emulsions can be used to reduce the fat in products while retaining consumer acceptability. They consist of an inner aqueous phase (w1), trapped as small droplets inside larger oil droplets (o), which are subsequently dispersed into another aqueous phase (w2) by high speed mixing. By introducing small

aqueous droplets in the oil droplets, the amount of oil is decreased while maintaining the same oil droplet surface area. These emulsions can also modulate temporal flavour release and thus can indirectly influence sweetness and saltiness perception. However, stability problems during food processing may occur (Oppermann *et al.* 2015). Gelation of the inner aqueous phase w1 by gelatine or whey protein isolate has been found to significantly increase stability and yield of w1/o/w2 multiple emulsions after preparation in term of storage, shear constraint and heat treatment compared to reference emulsions. Using this technique, fat reduction by up to 47% can be achieved with multiple emulsions while maintaining or even enhancing the sensory perception of fat-related attributes in the product, such as thickness, creaminess and fattiness (Oppermann *et al.* 2017). This indicates that the sensory perception of the emulsions may be mainly determined by the total oil droplet surface area. Sunflower oil was to make the w1/o/w2 emulsions for reformulation of the sauces, but emulsions can be prepared from diverse fat sources. These w1/o/w2 emulsions were found to be sensitive to osmotic and chemical stress, as is usually the case for reduced salt and sugar formulations. The resistance of the w1 droplets to osmotic stress was improved by transforming the w1 droplets into a gel (alginate or carrageenan based polymer), leading to a stable double emulsion gel in oil in water (g/o/w) during the product processing (Oppermann *et al.* 2015, Perez-Moral *et al.* 2014).

The reduction of salt in tomato-based sauce products was achieved by the addition of yeast extract, micronized salt, modified potassium chloride, garlic flavour and/or herbs, which enhanced consumers' perception of salty flavour. The efficacy of reducing the sugar content of sauces by adding stevia extract was tested on the low fat sauces prepared with double emulsions g/o/w. All these approaches had no effect on the double emulsion g/o/w stability and on the shelf-life of the product.

Using a combination of these strategies, tomato sauces with 20% reduction in sodium and 30% reduction in fat, and sweet creams with 30% reduction in sugar and 30% reduction in fat were produced. Consumers were unable to detect any sensory differences between the original and reformulated products.

Reducing sugars and fat in bakery products

In sweet bakery products, such as muffins, fat helps to incorporate air bubbles into the batter during mixing, leaven the product, tenderise the crumb, impart moistness and enhance mouthfeel. Sugar is responsible for the sweet taste, Maillard browning and many other properties related to the structure and texture. The main consequence of reducing sugar is a lower viscosity of the batter which leads to less air retention, thus lower aeration of the crumb. Concurrently, a reduction in sugar content leads to higher availability of water, which lowers the protein denaturation and starch gelatinisation temperature. Research conducted as part of *TeRiFiQ* indicated that considerable overall fat reductions in muffins did

not have a strong influence on its textural properties. Discrimination sensory tests were conducted with naïve consumers to determine the fat and sugar reduction levels that can be achieved without consumers perceiving differences in sensory properties. Simultaneous reduction by 40% for fat and 10% for sugar were possible without consumers perceiving differences relative to the standard muffins. The use of water-in-oil-in-water (w1/o/w2) multiple emulsions, as described above, is also a potential method for the reduction of fat in bakery products

The production of reduced fat and sugar muffins at an industrial scale was achieved using inulin as a fat and sugar replacer. This achieved simultaneous reduction of 25% fat and 25% sugar without any perceived differences in sensory properties in comparison with the regular muffin. A similar strategy with different types of inulin, polydextrose or waxy starch was successfully used in the production of Madeleines, a traditional sponge cake. An enhancement in perception of sweetness of sugar reduced products was also successfully achieved by the addition of specific sweetness-associated aroma compounds.

Consumer experiences with the reformulated foods

The most promising reformulated food products of the *TeRiFiQ* project were produced at an industrial level and consumer acceptability was examined in real-life and laboratory settings (Romagny *et al.* 2017) (Table 2).

One hundred and forty four consumers were recruited for the study, which used a cross-over design with each consumer provided with two bags of food products, the first to be consumed at home over a two-week period, followed by a two week interval, after which the second bag of products was consumed at home over the final two-week period. One bag contained reformulated foods developed in *TeRiFiQ*: lower salt lower fat Chorizo and low salt low fat dry-fermented sausages (Boadas), low salt low fat cooked sausages (Leiv Vidar), low salt semi-hard cheese (Orval) and low sugar low fat muffins (Millba). The other bag contained corresponding non-reformulated foods. Subjects were free to prepare and eat the samples as they pleased. When consuming the products at home, they were required to rate the pleasantness of the foods and consider the price they would be willing to pay for each. Following these evaluations, the real price was revealed and subjects were instructed to re-evaluate the price they were willing to pay.

Results indicated that the reformulated chorizo and dry sausages products were rated as more pleasant than the non-reformulated products. For the semi-hard cheese and muffins, no

difference in pleasantness was found between the reformulated and non-reformulated versions. Only the reformulated cooked sausages were considered less pleasant than the non-reformulated versions and this was mainly due to textural differences. The amount that subjects were willing to pay for the reformulated chorizo and dry sausages was about 12% higher than for the non-reformulated versions. For the semi-hard cheese, cooked sausages and muffins, no difference in the amount that participants were willing to pay was found between the reformulated and non-reformulated versions. Thus, for most of the products reformulated in the *TeRiFiQ* project, reformulation at least maintained consumer acceptability in real-life conditions.

In a follow up session in the laboratory, the participants were asked to rank reformulated and non-reformulated products along with other similar commercially available products (trademark and store-brand) in order of their pleasantness. There was no difference in ranked order of pleasantness between the reformulated and non-reformulated versions of the semi-hard cheeses and muffins. Moreover, both reformulated and non-reformulated muffins were ranked higher than the other commercial muffin products. The reformulated chorizo and dry sausages were ranked higher than the non-reformulated versions and were considered to be similar in pleasantness to the store brand version. However, the reformulated cooked sausages were ranked lower than the non-reformulated versions, and the store and the trademark brands. Surprisingly, in most cases, the trademark versions tended to be ranked lower in pleasantness than the store brand versions.

Conclusion

TeRiFiQ showed that the binary reduction approach (sodium/fat and sugar/fat) can be used to reduce the amount of sodium, fat and sugars in categories of foods that contribute significantly to intake of these nutrients in Europe, and sensory manipulations can be used to compensate for any changes in consumer acceptability. For most food products studied in *TeRiFiQ*, reformulation maintained the sensory quality of the products and consumer acceptability. Moreover, the reformulated products maintained their competitiveness in the market. Based on the findings of the *TeRiFiQ* project, the following recommendations are made.

- The use of double emulsion is a promising strategy to significantly reduce the fat content of various foods while maintaining consumer acceptability. This strategy might be transferable, at the industrial level, to fat-rich liquid or semi-liquid matrices such as mayonnaises, soups, sweet

and salty sauces, and to fat-rich solid matrices such as bakery products. However, regulatory and additional cost aspects should be taken into account.

- There is no universal strategy to the reduction of salt, fat and sugars in foods; instead strategies need to be adapted and fine-tuned to support the functional properties and flavour of individual target foods. In most of the cases the ambitious reduction targets were reached with a good acceptability of the reformulated products by consumers.

- Reformulation resulting in only minor changes to the original/traditional product is generally well accepted by consumers. However, consumer acceptance of the reformulation of traditional products is product and innovation type dependent (see FP6 'Truefood' project; www.truefood.eu).

- The strategies developed in *TeRiFiQ* can be translated and applied at industrial scale, but additional costs may occur due to additional processing steps. The SMEs involved in *TeRiFiQ* were able to develop new reformulated food products which were competitive in the market. Some of these reformulated products are already available in Europe.

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Figure 1: Organisation of *TeRiFiQ* project

Logo of *TeRiFiQ* project

Table 1: Strategies used to reduce the sodium, fat and sugar in cheeses, processed meat products, bakery products and sauces. Reformulated products acceptable (+) and not acceptable (-) to consumers

Products	**Sodium***	**Fat***	**Sugar***	**Approach**	**Consumer acceptability**
Cheeses					
Raclette	-14% -29%			Adjustment of process parameters (e;g; involvingBrine composition, time…)	+
Brie	-16% -24%			Adjustment of process parameters (e;g; involvingBrine composition, time…)	+
Trappist	-27%, -36%			Adjustment of process parameters (e;g; involvingBrine composition, time…)	+
Smear soft cheese	-10%			Adjustment of process parameters (e;g; involvingBrine composition, time…)	-
Brie	-30%	-8%**		Use of milk higher in unsaturated fatty acids achieved by changing the cow's diet	+
Processed meat products					
Cooked sausages	-20%	-24%		Use of inulin, pre-rigour meat	+
Dry sausages	-35%	-70%§		Use of potassium chloride, yeast extracts, flavouring, sunflower oil, emulsions, fibres, lean meat	+
Chorizo	- 40%	-60%§		Use of potassium chloride, yeast extracts, flavouring, sunflower oil, emulsions, fibres, lean meat	+
Bakery products					
Muffins		-40%	-25%	Use of inulin, gelified double emulsion	+
Madeleines		-30%	-30%	Use of polydextrose, double emulsion	+
Sauces					
Tomato sauce for Pizza	-20%	-30%		Use of salt replacers, gelified double emulsion	+

Sweet cream	-30%	-30%	Use of stevia, aromas, gelified double emulsion	+

* The % indicates the main reductions achieved during the project for the overall fat content.

**The value corresponds to saturated fat content lowered in Brie cheese although total fat was unchanged.

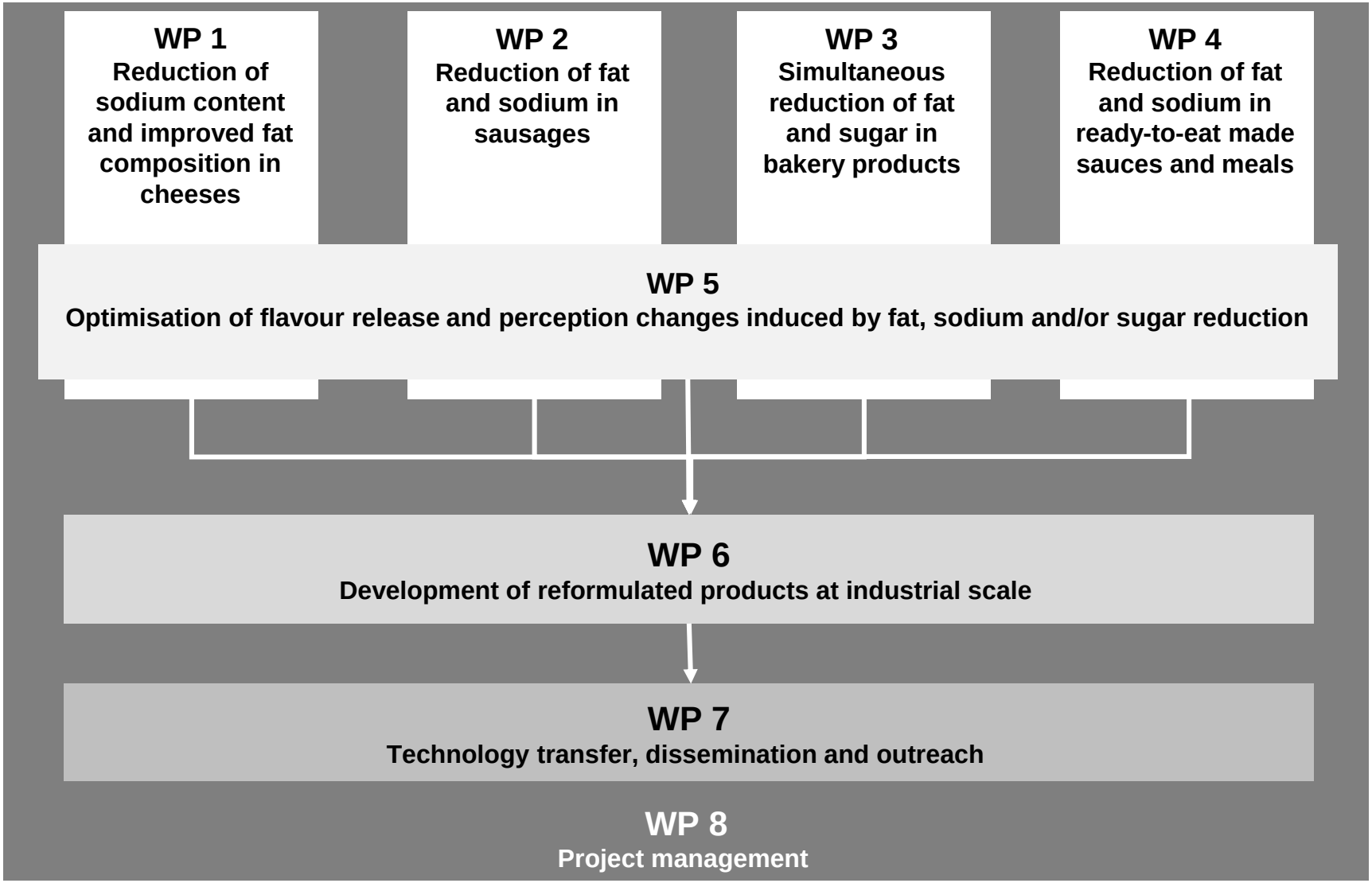
§ The values correspond to saturated and overall fat contents lowered in the dry meat products.

Table 2: Pleasantness, willingness to pay and sorting task scores for the non-reformulated products (NR) and the reformulated products (R)

Product (Composition of a shopping-bag)	Pleasantness R/NR	WTP R/NR	Sorting task (liking)
Semi-hard cheese (200g)	=	=	NR = R > Store brand = Trademark
Dry sausages (75g)	>	>	R = Store brand > Trademark > NR
Chorizo (40g)	>	>	R > Store brand > NR = Trademark
Cooked sausages (400g)	<	=	Store brand = Trademark = NR > R
Muffin (200g)	=	=	NR = R > Store brand = Trademark

=: score not significantly different; >: higher score; <: lower score

(Figure 1)


WP 1
Reduction of sodium content and improved fat composition in cheeses
WP 2
Reduction of fat and sodium in sausages
WP 3
Simultaneous reduction of fat and sugar in bakery products
WP 4
Reduction of fat and sodium in ready-to-eat made sauces and meals
WP 5
Optimisation of flavour release and perception changes induced by fat, sodium and/or sugar reduction
WP 6
Development of reformulated products at industrial scale
WP 7
Technology transfer, dissemination and outreach
WP 8
Project management