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FOOD REFORMULATION

Assessment of possibilities for reformulation of main food products

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Summary

The presented publication summarises the current state of knowledge on food reformulation, whilst taking into account current nutritional aspects. The book covers all major food commodities i. e. bakery products, meat products, dairy products, confectionery, edible fats and oils, non-alcoholic drinks, fruit and vegetable products. The text itself provides an overview of possible reformulations of selected food commodities, including technological and sensory limits as well as legislative constraints. The aim of the book is to familiarise the specialist in the field with this topic and to help manufacturers implement selected food reformulation interventions. This book was written by experts from the University of Chemistry and Technology, Prague, the University of Veterinary and Pharmaceutical Sciences Brno and Federation of the Food and Drink Industries of the Czech Republic.

Introduction

The main goal of the food industry was and is to provide enough safe and quality food for a wide range of consumers. The industry is responding to the increased interest in a healthy lifestyle through a number of measures, in which changes to recipes – reformulation – are a key part. Reformulation is meant to be positive, meaning that it should offer the consumer some benefits, especially with regard to nutrition, while considering the current state of knowledge about nutrition. However, the benefits brought about by this trend may also entail certain risks, especially with regard to product stability and safety. Recipes that have remained unchanged for many decades have undergone significant modification, and the food industry has not always been properly prepared to implement these changes. The presented monograph published by the Federation of the Food and Drink Industries of the Czech Republic seeks to evaluate the possibilities for reformulating the main food commodities and thus facilitate the difficult work of the development of reformulated products in practice.

For the team of authors:

Aleš Rajchl

The book is divided into individual chapters by food commodities and is accompanied by references to the original sources. Experts from the University of Chemistry and Technology, Prague, the University of Veterinary and Pharmaceutical Sciences Brno, and the Federation of the Food and Drink Industries of the Czech Republic participated in the creation of this book.

Food industry and reformulation

Hrabcová M.

Nowadays, consumers have access to a wide range of foods yet our hectic modern lifestyles are leading to increased demands. Many people are overweight due to unbalanced diet and lack of exercise yet most of them want to enjoy good food and "eat and live with passion". This requires a diverse range of food on the market, frequently a tough challenge for food producers.

Food producers in the Czech Republic are aware that they can help improve the health of consumers, in particular by offering a wide range of products in "standard" form or with reductions in some nutrients, lower calories or improved nutritional composition. In accordance with the National Strategy for Health Protection and Promotion and Disease Prevention - Health 2020 government program, food producers in the Federation of the Food and Drink Industries of the Czech Republic (hereinafter the "FFDI") and the Czech Technology Platform for Foodstuffs established the Platform for Reformulation (hereinafter the "PfR") in the autumn of 2016. This was the first systematic act in the area of reformulation as a whole, even though similar activities have been going on for many years in companies. The PfR has set itself the goal of creating an expert forum for discussing individual reformulation objectives and technologies, within which PfR members can:

- set and communicate specific commitments on reformulation and support for healthy nutrition until 2020;
- monitor and report achievements and share experience with other producers;
- educate the public in collaboration with the academic community and relevant ministries.

The first year's activity of the PfR resulted in the signing of the Healthy Lifestyle Declaration by the President of the FFDI and the Chief Public Health Officer of the Czech Republic. In this document, FFDI members undertake to pursue activities under the Ten Pillars of the Nutrition Policy of the Food Industry, to supplement, update and assess these activities on a continual basis, and to share the results with the Ministry of Health, the media and the professional and general public.

The Ten Pillars of the Nutrition Policy include voluntary commitments in terms of:

1. promoting a healthy lifestyle,
2. developing and producing innovated and reformulated products (improved macronutrient content),
3. expanding their offer with products with im-

proved content (improved micronutrient and other component composition),

4. offering a diverse range of products and packaging,
5. informing consumers over and beyond legislative requirements,
6. promoting products in a responsible manner,
7. educating consumers and the public,
8. publishing results, educating and sharing experience with each other,
9. promoting a healthy lifestyle and physical activity,
10. cooperating with the relevant institutions, academic spheres, experts, the media and other stakeholders.

The contribution towards the improvement of nutritional trends and health of the Czech population is understood by the food industry as being of a long-term nature. Hence the Healthy Lifestyle Declaration and the Ten Pillars of the Nutrition Policy are a living document: in addition to assessing past activities, the document is regularly updated and new goals set for the next year or longer. The results achieved are regularly published as part of the annual PfR conference which, thanks to the participation of representatives of state administration, science and research, doctors and nutritionists, not only enables an assessment of what producers have "improved" in food composition on the Czech market, but also discussion of the importance of reformulation for health, the future direction of reformulation and the necessary technologies.

Although the PfR has already registered considerable success and a number of products with reduced sugar, salt, trans fatty acid content or with an improved structure enriched with, for example, fibre, vitamins and minerals have appeared on the Czech market, producers still face a number of problems.

Recipe adjustments must be made gradually so that the consumer accepts the change. A drastic reduction will be significantly reflected in the sensory properties of the product and the consumer then rejects such product. Unfortunately, the current European legislation on food labelling makes it impossible to inform about a reduction in certain nutrients unless the reduction limit – usually 30% – is reached. However, such a recipe modification is unrealistic in practice due to the above-mentioned consumer acceptance issue, and so producers tend to adopt gradual reductions in nutrients. They cannot provide information about a reduction of less than 30% either on the product packaging or in other materials (websites, infolines, brochures etc.) One solution is the possibility of an award in the competition "Award of the Federation of the Food and Drink Industries of the Czech Republic for the Best Innovative Food Product" in the "Reformulation of the Year" category. The award-winning product can use the "Reformulation of the Year" logo to inform consumers that the product has been improved or reformulated.

Another problem area is the lack of consumer awareness. They often understand reformulation as an effort by producers to skimp and perceive recipe adjustments as "cheating". The reformulated product is then at a competitive disadvantage compared to "normal" products, which of course discourages the producer from reformulation.

Last but not least, it must be considered that the planned recipe modification must be technologically feasible and must maintain the required sensory properties. Sugar, salt and fat not only have nutritional functions but often play the role of preservative, or taste or volume enhancer. When they are reduced, it is often necessary to choose a substitute that may have a controversial perception (e.g. more additives, E numbers, artificial sweeteners, etc.) Therefore, this study has been developed to better clarify this issue and explain certain technological constraints.

Legislative aspects of reformulation

Chýlková M.

The food industry is aware of its important role in improving the nutritional composition of foods and uses the latest scientific and technological knowledge to better respond to the needs and wishes of consumers and to market products with improved composition. It addresses much more than only improving sensory properties, focusing also on improving the health and nutritional structure aspects. However, despite its good efforts, it is very often bound by the applicable legislation which sets the framework for how to communicate the benefits of such "improved" foods.

In new recipes, reductions in sugar, fat and salt content, improvements in the structure and composition of some macronutrients such as the removal of trans fatty acids (hereinafter "TFA"), reductions in saturated fatty acids, or increases in protein content are very common. The changes are either in the form of reformulation, meaning improving the structure of an existing product, or through innovation, i.e. by introducing a brand-new product with improved composition.

At the same time, the food industry offers a wide range of products and packaging allowing each consumer to compose a diverse and balanced diet thanks to the mandatory nutrition declaration on foods. In addition to standard products, this offer includes low-calorie products, different portion sizes or single-serve products. However, the legislation in force, in particular Regulation (EU) No 1169/2011 on the provision of food information to consumers (hereinafter "Regulation (EU) No 1169/2011"), lays down a predefined range of data that must be provided on a mandatory basis (the so-called seven points: energy value, fats, saturated fatty acids, carbohydrates, sugars, proteins and salt) as well as data that can be voluntarily provided (e.g. information on fibre content), while the voluntary information is far from covering everything the consumer would like to read on the food packaging (typically information about the TFA or cholesterol content, which is non-permitted nutrition information).

However, a major issue for many producers is how to communicate the reduced content of a certain nutrient. Does it look unbelievable? From the perspective of the requirements of current legislation it is not so unbelievable because they impose relatively strict conditions on when a reduction or increase in a certain nutrient or other substance can be communicated.

In 2006, the EU adopted rules for presenting voluntary claims on foods and beverages relating to nutritional and health benefits, namely Regulation (EU) No 1924/2006 on nutrition and health claims made on foods (hereinafter "Regulation (EU) No 1924/2006"). Regulation (EU) No 1924/2006 applies to nutrition and health claims made in commercial communication, whether in the labelling and presentation of foods or in advertising relating to food to be delivered to the final consumer, and also to foods intended for delivery to restaurants, hospitals, schools, canteens and similar catering facilities.

According to Regulation (EU) No 1924/2006, a "claim" means any message or representation which is not mandatory under Community or national legislation, including pictorial, graphic or symbolic representation, in any form, which states, suggests or implies that a food has particular characteristics; a "nutrition claim" means any claim which states, suggests or implies that a food has particular beneficial nutritional properties due to:

a) the energy (calorific value) it
  - provides,
  - provides at a reduced or increased rate, or
  - does not provide; and/or
b) the nutrients or other substances it
- contains,
- contains in reduced or increased proportions, or
- does not contain.

In contrast, a "health claim" means any claim that states, suggests or implies that a relationship exists between a food category, a food or one of its constituents and health.

In view of the impact of reformulation on product-specific communication, food producers are primarily bound by the rules on nutrition claims (in most cases, the possibility to present an approved health claim also most commonly depends on the conditions for the use of a nutrition claim). These concern not only the content of individual vitamins or minerals but also the total energy value and the content of sugar, salt, fat and other substances or nutrients (Annex to the mentioned Regulation) and specify the precise conditions under which the claims may be used:

- "low energy" may be used where the product contains no more than 40 kcal (170 kJ) per 100 g for solids or more than 20 kcal (80 kJ) per 100 ml for liquids;
- "energy-reduced" may only be used where the energy value is reduced by at least 30% (at the same time indicating the characteristic(s) which make(s) the food reduced in its total energy value;
- "energy-free" can only be used where the product contains no more than 4 kcal (17 kJ) per 100 ml. For table-top sweeteners the limit of 0.4 kcal (1.7 kJ)/portion, with equivalent sweetening properties to 6 g of sucrose (approximately 1 teaspoon of sucrose), applies;

- "low-fat" can only be used where the product contains no more than 3 g of fat per 100 g for solids or 1.5 g of fat per 100 ml for liquids (1.8 g of fat per 100 ml for semi-skimmed milk);
- "fat-free" may only be used where the product contains no more than 0.5 g of fat per 100 g or 100 ml. However, claims expressed as "X% fat-free" shall be prohibited;
- "low-saturated fat" may only be used if the total sum of saturated fatty acids and trans fatty acids in the product does not exceed 1.5 g per 100 g solids or 0.75 g per 100 ml for liquids and in either case the total sum of saturated fatty acids and trans fatty acids must not provide more than 10% of the energy;
- "saturated fat-free" may only be used where the sum of saturated fat and trans fatty acids does not exceed 0.1 g of saturated fat per 100 g or 100 ml;
- "low sugar" may only be used where the product contains no more than 5 g of sugar per 100 g for solids or 2.5 g of sugar per 100 ml for liquids;
- "sugar-free" may only be used where the product contains no more than 0.5 g of sugars per 100 g or 100 ml;
- "with no added sugar" may only be used where the product does not contain any added mono- or disaccharides or any other food used for its sweetening properties. If sugars are naturally present in the food, the following indication should also appear on the label: "CONTAINS NATURALLY OCCURRING SUGARS".
- "low sodium/salt" may only be used where the product contains no more than 0.12 g of sodium or an equivalent amount of salt per 100 g or 100 ml. For waters, other than natural mineral waters falling within the scope of Directive 80/777/EEC, this value should not exceed 2 mg of sodium per 100 ml;
- "very low sodium/salt" may only be used where the product contains no more than 0.04 grams of sodium or the equivalent amount of salt per 100 grams or 100 millilitres. This claim shall not be used for natural mineral waters and other waters;
- "sodium-free/salt-free" may only be used where the product contains no more than 0.005 g sodium, or the equivalent value of salt per 100 g;
- "with no added sodium/salt" may only be used where the product contains no sodium/salt or any other component containing sodium/salt and the product contains no more than 0.12 g of sodium or the equivalent value of salt per 100 g or 100 ml;
- "source of fibre" may only be used where the product contains at least 3 g of fibre per 100 g or at least 1.5 g fibre per 100 kcal;
- "high fibre" may only be used where the product contains at least 6 g fibre per 100 g or at least 3 g of fibre per 100 kcal;
- "source of protein" may only be used where at least 12% of the energy value of the food is provided by protein;

- "high protein" may only be used where at least 20% of the energy value of the food is provided by protein;
- "source of (name of vitamin/s) and/or (name of mineral/s)" may only be used where the product contains at least a significant amount of vitamins or minerals as defined in the Annex to Regulation (EU) No 1169/2011 or an amount provided for by derogations granted according to Article 6 of Regulation (EC) No 1925/2006;
- "high (name of vitamin/s) and/or (name of mineral/s)" content may only be used where the product contains at least twice the value of "source of";
- "contains (name of the nutrient or other substance)", for which specific conditions are not laid down, may only be used where the product complies with all the applicable provisions of the Regulation, and in particular Art. 5. For vitamins and minerals the conditions of the claim "source of" shall apply;
- "increased (name of nutrient)" may only be used where the product meets the conditions for the claim "source of" and the increase in content is at least 30% compared to a similar product;
- "reduced (name of nutrient)" may only be used where the reduction in content is at least 30% compared to a similar product, except for micronutrients where a 10% difference in the reference values as set in Regulation (EU) No 1169/2011 shall be acceptable and for sodium, or the equivalent value for salt, where a 25% difference shall be acceptable.
- The claim "reduced saturated fat", and any claim likely to have the same meaning for the consumer, may only be made in the following cases:

a) if the sum of saturated fatty acids and trans fatty acids in the product bearing this claim is at least 30% less than the sum of saturated fatty acids and of trans fatty acids in a similar product;
b) if the content in trans fatty acids in the product bearing this claim is equal to or less than in a similar product.

The claim "reduced sugars", and any claim likely to have the same meaning for the consumer, may only be made if the energy value of the product bearing this claim is equal to or less than the amount of energy in a similar product;

- "light/lite" may be used where the product meets the conditions for the term "reduced". This claim shall also be accompanied by an indication of the characteristic(s) which make the product "light" or "lite";
- "naturally/natural" may be used where a food naturally meets the conditions laid down in the Annex for the use of a nutritional claim;
- "source of omega-3 fatty acids" may only be used where the product contains at least

0.3 g alpha-linolenic acid per 100 g and per 100 kcal, or at least 40 mg of the sum of eicosapentaenoic acid and docosahexaenoic acid per 100 g and per 100 kcal;

- “high omega-3 fatty acids” may only be used where the product contains at least 0.6 g alpha-linolenic acid per 100 g and per 100 kcal or at least 80 mg of the sum of eicosapentaenoic acid and docosahexaenoic acid per 100 g and per 100 kcal;
- “high monounsaturated fat” may only be used where at least 45% of the fatty acids present in the product derive from monounsaturated fat and under the condition that monounsaturated fat provides more than 20% of energy of the product;
- “high polyunsaturated fat” may only be used where at least 45% of the fatty acids present in the product derive from polyunsaturated fat and under the condition that polyunsaturated fat provides more than 20% of energy of the product;
- “high unsaturated fat” may only be used where at least 70% of the fatty acids present in the product derive from unsaturated fat under the condition that unsaturated fat provides more than 20% of energy of the product.

The most important step in communicating a successful result for a reformulated product is to tell the consumer that the producer has e.g. reduced the salt or sugar content of the product. However, here the producer starts to face the insurmountable obstacle stated in the Regulation for claims regarding a reduced amount of a particular nutrient:

- “reduced (name of the nutrient)” may only be used where the reduction in content is at least 30% compared to a similar product, except for micronutrients where a 10% difference in the reference values as set in Regulation (EU) No 1169/2011 and for sodium, or the equivalent value for salt, where a 25% difference shall be acceptable;
- “reduced saturated fat”, and any claim likely to have the same meaning for the consumer, may only be made in the following cases:

  - if the sum of saturated fatty acids and of trans fatty acids in the product bearing the claim is at least 30% less than the sum of saturated fatty acids and of trans fatty acids in a similar product;
  - if the content in trans fatty acids in the product bearing the claim is equal to or less than in a similar product.

- The claim “reduced sugars”, and any claim likely to have the same meaning for the consumer, may only be made if the amount of energy of the product bearing the claim is equal to or less than the amount of energy in a similar product.

Such a high “first attempt” reduction is very often unrealistic – reduction takes place gradually and in very small steps. Therefore, it is de facto impossible to inform consumers of any reduction that is less than the amount set for the nutrient or substance in question under the applicable legislation.

Food reformulation and bakery products

Sluková M., Skřivan P.

Bread and bakery products as an important source of salt in human nutrition

Bread as an essential part of human nutrition

Bread in various forms has accompanied mankind since the Neolithic agricultural revolution and was an essential part of human nutrition for millennia. There was not a long way to go from simple, virtually unleavened flatbread to fermented breads, but the technologies for maximum fermentation process control, ensuring bread stability and the standardization of its shape, volume, structure and soft inside texture as well as a whole spectrum of organoleptic properties have been gradually developed over a period of several thousand years. Preferences regarding requirements for the sensory properties of bread have been shaped by geographical and cultural conditions. At the same time, the requirements for cereals, now known as bread cereals, have been refined. On a global scale, wheat is the predominant and key cereal in bread, supplemented to a lesser extent by rye in central, northern and eastern Europe, and rather rarely by oats or barley in other places. Bread is most often produced according to very simple recipes, with minimal added sugar or fat, and often without them. Leavening is based on fermentation processes, the vast majority worldwide using ethanol fermentation from baker's yeast; in European countries, including the Czech Republic, complex processes based on rye fermentation control including lactic and ethanol fermentation side by side are applied to rye and wheat (wheat-and-rye) breads *(Skřivan, Sluková, 2016)*.

Figure 1: Rye grain and sourdough wheat-rye bread

In spite of some – often unjustified – objections to wheat in recent years, the expert nutritional view of bread is largely favourable, with the proviso that wheat as well as wheat-and--rye bread (most widely used in our country and known as "konzumní" bread) have a relatively high glycaemic index (GI = 65-70) due to the high starch content. Yet this also applies to potatoes, rice, etc. Breads with a higher proportion of rye flour raised with rye leaven, which contain more arabinoxylans (a nutritionally important component of fibre), are more favourably evaluated. A slight GI reduction is possible through the addition of darker rye flours (while rye bread flour with an ash content of around 1% is used in our country, flour with an ash content of 1.3-1.5% is used in Germany for the production of regular breads). This is also something of a challenge for reformulation, which would in turn be an economic boost for mills and bakeries *(Skřivan, Sluková, 2015a; Sluková, Skřivan, 2016)*.

Figure 2: Special impact mill for the production of fine wholegrain flour with a reduced glycaemic index

Salt content in bread and ordinary bakery products

However, the main concern about bread is its salt content, around 1–1.5%. The salt content of these products recommended by the WHO should be ≤ 1.2%, with our "konzumní" breads often exceed by 0.1–0.3% *(Brat et al., 2015)*. Bread is considered a basic source of salt intake (in the form of Na^+ ions) in human nutrition. This is despite the fact that the salt content is relatively low in bread compared to other types of food. The problem is that, unlike these foods, bread is one of the most widespread dietary components, consumed on a practically daily basis. Reducing the salt content of bread by several tenths of a percent is therefore of great importance. Cereal products make up 33% of the daily salt intake (hereinafter the "DSI"), meat products make up 26% of the DSI and dairy products 8% of the DSI. However, there are at least two issues that complicate such a trend. One is sensory quality – the slightly salty taste is intrinsic to bread – the other is technology. Salt significantly contributes to the internal structure of the dough, especially to the viscoelastic properties of the protein complex, and thus to the rheological properties and processability of the dough. Reducing salt to a tolerable minimum is therefore often a relatively difficult task *(Salovaara, 2009; Kaur et al., 2011; Šedivý et al., 2015; Ambrosewicz-Walacik et al., 2016)*.

Ordinary bakery products are practically the same as bread as concerns GI, sugar, fat and salt content. The proportion of sugar and fat in bakers' recipes is very low, and for the same reason as with bread (frequency of consumption) there are reservations about the salt content. Salt is also used in some of our typical sprinkled bakery products (rolls, buns).

Health aspects of salt content in bread and ordinary bakery products

The sodium cation together with the potassium cation is the main physical regulator of blood pressure. It ensures the transmission of nerve impulses and is an essential component for proper muscle function. It serves as an activator for many enzymes and as a mediator in the transport of nutrients to the intestines, kidneys and other organs and tissues. The minimum daily salt intake for an adult is about 1.5 g, which corresponds to about 4 g of salt (multiplication coefficient of 2.5) *(Kohlmeier, 2003)*. The recommended daily salt intake for adults is 5-6 g. However, the actual daily intake is more often 9-12 g and in some countries, especially in the Balkans, salt consumption is up to 16 g/day. The correlation between high salt intake and increased blood pressure has been clearly demonstrated *(Quilez, Salas-Salvado, 2012; Leatherhead Food Research, 2010)*. Long-term elevated blood pressure can lead to a variety of health issues, such as cardiovascular disease, coronary heart disease, heart attack, stroke and heart failure *(He, MacGregor, 2003)*. The US Food and Drug Administration (FDA) has therefore permitted the inclusion on packaging and product labels of the claim that a low sodium diet reduces the risk of high blood pressure *(Kvasničková, 2008)*.

According to a survey conducted in 2010, reducing the daily salt intake from 10 g to 5 g worldwide would lead to a 17% reduction in cardiovascular disease (WHO, 2010). High blood pressure is associated with increased risk of kidney disease, left ventricular hypertrophy and albuminuria. Almost 80% of consumed salt comes from processed foods, 10% from foods with natural salt content and 10% from salt used in cooking and seasoning *(Quilez, Salas-Salvado, 2012)*.

Technological aspects of salt use in bread and baked goods production

Salt is one of the basic ingredients of dough recipes for the production of bakery products (flour, salt, sugar, fat and yeast). The sensory perception (salty taste, full flavour) is important for cereal products, but the essential importance of technology is not to be overlooked either. As already mentioned above, wheat – most commonly common wheat (*Triticum aestivum* L.) – is by far the most widely used cereal for the production of bread and bakery products both globally and in this country. Wheat flour is mainly used because of the unique properties of its proteins. Unlike most other proteins, wheat prolamins and glutelins (called gliadin and glutenin in this case) swell with water only to a limited extent, and at the same time when energy and oxygen from the air are added through mechanical work (kneading) they create a solid gel we call gluten. This then forms the supporting "skeleton" of the dough, is the cause of the ductility and elasticity of the dough and gives the product its final shape. Gluten formed in this manner makes wheat dough unique in its texture and sensory properties *(Skřivan, Sluková, 2015b)*. The amount of salt added to the dough is typically in the range of 1-2% by weight based on the weight of the flour. The salt is applied either in loose form, which is very soluble and easy to dispense, or in liquid form as a concentrated-to-saturated solution (brine), the concentration of which is 26-29% at normal operating temperatures *(Grayish et al., 2015)*.

Figure 3: Standard roller mills for conventional flour production

However, the addition of about 1% of salt (based on the weight of the flour) is sufficient to achieve the above-mentioned technological effects (on the structure of the gluten). Higher amounts of salt are added mainly to influence the taste of the product. This is not only about achieving a salty taste, but rather the so-called "full" taste of the product in combination with a defined amount of sugar *(Příhoda et al., 2003)*. Surveys have shown that consumers perceive products with a low salt content to be more friable, older and stiffer.

Another significant effect of the salt can be seen in the fermentation of the dough. Salt in the amounts used (1-2%) limits yeast activity, thereby reducing CO_2 production and subsequently slowing down the maturation process of yeast and dough. For this reason, it is inappropriate to apply the salt at the fermentation stages, when increased microorganism physiological activity is desired. This effect can be taken advantage of when it is necessary to slow down the fermentation of the dough at a higher temperature and thus avoid excessive ethanol fermentation. While the addition of 2% of salt reduces yeast activity by up to 20%, the addition of less salt (about 0.5%) can in turn stimulate yeast activity and accelerate fermentation processes *(Salovaara, 2009)*.

Possibility of reducing the salt content in baked goods

Substances other than sodium chloride also provide a salty taste, but this taste is usually accompanied by other, often undesirable flavours such as a bitter or metallic aftertaste. Indeed, only sodium chloride has a purely salty taste *(Velíšek, Hajšlová, 2009)*. It should be noted that even though Na^+ and Cl^- ions form a salty taste, their presence in food may not automatically ensure its salinity. To achieve a salty taste, the two ions must have a 1:1 stoichiometric ratio *(Šedivý et al., 2015)*. One possibility for substituting salt in cereal products, or for limiting its negative effect on health, is the addition of potassium chloride (KCl) to the recipe. This is because potassium ions serve as blood-pressure regulators in the body and are in this sense a counterbalance to sodium ions. At the same time, most of the world's population exhibits below-average daily potassium intake, and the addition of KCl to dough would help prevent this deficiency *(Van Mierlo et al., 2010)*.

The problem is that potassium salt adds a bitter aftertaste to the product. When replacing edible salt with KCl, an undesirable change in taste was already detected at a 25% replacement ratio. One solution may be to use a combination of KCl or sodium glutamate to mask the bitter taste *(Toldra, Barat, 2009)*. By means of sensory assessments, the ideal amount of KCl was determined to be at most 20% of the original NaCl addition to ensure the adequate sensory quality of the product *(Salovaara, 2009; Kaur et al., 2011)*. Another experiment was to replace the problematic sodium ions with calcium ions. Nowadays, most of the world's population is predominantly deficient in calcium, especially school-age children, so salt substitution and calcium fortification seemed to be a suitable solution. Consuming 50 g of baked goods and replacing 50% of NaCl with $CaCl_2$ should theoretically provide 13.5–17.3% of the recommended daily allowance (hereinafter the "RDA") of calcium in children *(Basett et al., 2014)*. A study conducted in 2013 showed that a 50% salt substitution with $CaCl_2$ and $CaCO_3$ (with a 1:1 ratio) resulted in a partial reduction in ductility and elasticity of the dough and a reduction in dough stability. The experiments were based on an initial salt content of 1.8% of the weight of the flour. $CaCl_2$ addition caused increased hardness of the top crust and less hardness of the bottom crust. Increasing the proportion of calcium salts led to a lightening of the crust and soft inside. However, bread with 50% substitution was found to be comparable in taste to the control sample with added $CaCl_2$.

One novelty among products that reduce NaCl content while preserving the salty taste of a bakery products is a product from the British Tate & Lyle. It is called SODA-LO™ and is a microcrystalline salt intended, inter alia, for the production of cereal products. The base of the preparation is sea salt in a very finely granulated form mixed with maltodextrin and some water. The resulting mass is then dried in a spray dryer using a special patented process. As can be seen in **Fig. 4**, during drying hollow crystalline microspheres are formed which provide the preparation with a distinctive surface and specific microstructure. Thanks to its significantly greater specific surface area, this preparation provides a faster taste-bud response and thus achieves the same strong salty taste but with a lower sodium chloride content compared to commonly used granular salt.

Baked goods and sugar and fat issues

The rules for categorizing baked goods are not harmonized in the EU and are quite different in the individual EU Member States. For this reason, it is appropriate to recall the categorization under Czech legislation. According to Decree No 333/1997, implementing Section 18 a), b), g) and h) of Act No 110/1997, on food and tobacco products and on amending and supplementing some related laws, for grain mill products, pasta, bakery products and confectionery and doughs, as amended, bakery products mean products obtained by the heat treatment of doughs or masses, the dry matter of which is predominantly composed of grain mill products with the exception of whipped masses and meringue bakery products. Heat treatment means mainly baking, or frying, extruding or puffing in the case of smaller product parts. Whipped masses consist mainly of whipped egg whites or eggs, as the basic common ingredients are usually plain white or semi-white wheat flour for fine or ordinary bakery products. Other basic ingredients of baked goods are water, salt and baker's yeast for most biologically-leavened products. Fat is a commonly used ingredient for most bakery products and pastries. Today, this most commonly means vegetable oil.

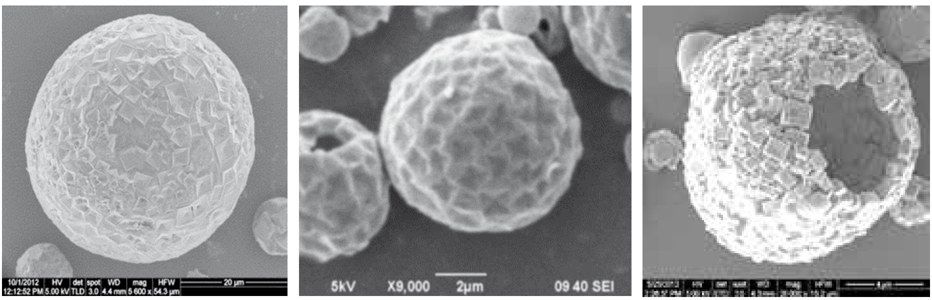

Figure 4: SODA-LO® Salt Microspheres (Internal materials, Tate & Lyle´s, https://www.tateandlyle.com/ingredient/soda-lo-salt-microspheres)

Fine pastry

Fine pastry means baked goods obtained by the heat treatment of doughs or masses with a formulation addition of at least 8.2% anhydrous fat or 5% sugar per total weight of used mill products, optionally including with various fillings before or after baking. However, as we will see from the detailed categorization, the contents of both these components are often significantly (even in orders of magnitude) higher, which is especially true for fat, which is often mostly saturated fatty acid esters, whether this is butter or hardened fat widely used in bakeries. Wheat-based goods made of white wheat flour are generally energy-rich thanks to their high starch content. In combination with the higher sugar and saturated fat, they are one of the causes of overweight and obesity, in this case very often also in children. It is therefore highly desirable to reduce the content of these substances or to substitute commonly used bakers' fats by adding oils with higher polyenoic fatty acids content *(WHO, 2015; Dostálová et al., 2010; Šedivý et al., 2016)*.

Puff pastry goods

The basic dough is prepared from flour and water. After being allowed to rest, the dough sheets are covered with a layer of solid fat. This is a special margarine that can be rolled out into thin sheets without tearing. The fat dough is refolded and rolled several times until a sufficient number of alternating sheets of dough and fat are obtained. To make puff pastry goods (formerly called confectionery to differentiate it from baker's yeast goods), no raising agents are used and leavening is ensured by water vapour between the thin sheets of the fat-interleaved dough. The usual fat formula is 70% of margarine based on the weight of the flour. There exist powerful automatic lines for dough production that ensure the repeated layering and rolling of the dough to achieve over 100 theoretical layers *(Dostálová, Kadlec, 2014)*.

Yeast-leavened puff baked goods

(or Danish baked goods)

The process of preparing a dough (formerly called baker's) is similar to that of puff baked goods, with the difference that the dough is leavened with yeast and the usual fat dose is 10% to the dough and 30% to the flour recipe for dough margarine interleaving.

Fine pastry goods made from yeast dough

There are two types of yeast dough products: filled dough products and stuffed products. In the past, these products were differentiated as baker's or confectionery. Confectionery products were always considered more luxurious and therefore products with fat (butter, margarine) in the dough recipe of at least 20% based on flour weight (Christmas cakes, Easter cakes, pies) were considered to be confectionery products. The current definition of confectionery products includes only stuffed products and does not address the fat content of the dough. Thus, only the differing definition for common and fine pastry applies differentiation by the fat content of the dough. The most common fine pastry products are Christmas cakes, Easter cakes, marble cakes, Stollen and several types of small sweet and non-sweet fine pastry (formerly called salty croissants), banquet rolls (25 g) with a 10% margarine formula based on flour weight, and sweet and Carlsbad croissants with an 18% margarine formula based on flour weight. Easter cakes with their traditional loaf shape remain a seasonal product. With regard to the dough, Easter cakes are usually the same as Christmas cakes. Yeast dough cakes are relatively rarely produced without a filling, and the dough recipe is not rich. Conversely, a Stollen is traditionally made from dough with a higher fat content (the so-called baker's approx. 18%, confectioner's 22-25% based on flour weight) and, according to the traditional process, are baked with clarified butter and immediately wrapped in icing sugar.

Fried products from yeast dough

These products are either filled after frying or unfilled. The definition of fine pastry indicates that filled products are filled before baking (as opposed to confectionery products), with the sole exception being products filled with fruit preserves and spreads and microbially stable fillings. This exception also applies to filled fried products, i.e. especially donuts. Unfilled fried products are mainly rolls and other braided shapes. Traditional donut dough is prepared with about 12% oil based on flour weight and rum added to the dough. Apricot jam was previously required to fill traditional donuts. Currently, various fat creams are used as fillers, and sometimes sugar or cocoa toppings with hardened fat are also used.

In addition to yeast-leavened doughs, fine pastry is also made from other materials, for which we will mainly focus on the content and type of fats used. Once again we see that the fat content often exceeds the limit set by the decree. Yet it would be misleading to believe that the solution is simply to reduce the fat content. The fat content of the products indicated in the following list is fundamentally determined by their characteristic organoleptic properties.

Other types of fine pastry

This is fine pastry made of batter: the material is prepared with an oil content of about 18% based on flour weight and leavened with baking powder. Whipped pastries: traditionally, the materials were first prepared by whipping eggs and gradually adding other ingredients. Today, the raw materials can be whipped simultaneously using rapid-whisking agents (foam stabilizers), whereby the fat content is usually in the range of 10-30% based on flour weight. Furthermore, sponge cake products: these products have a high fat content, with a recipe based on dough with e.g. 37% margarine and 6–37% egg yolk by type of matter. Typical products are cakes, biscuits and seasonal holiday products (lamb and fish shapes).

In terms of fat content and frequency of consumption, products made of brittle dough are also important, where traditional products have a higher fat content with dough formulas calling for 32% based on flour weight, or popular salty or cheese pastries, salted sticks and the like. These products can contain a high proportion of salt but may also be unsalted. However, it cannot be guaranteed there is no added sugar in the dough. Salt can only be added in larger quantities if sprinkled on. Grated or sliced cheese on the surface may also be part of a dough recipe. Again, the fat content is in the 10-30% range based on flour weight.

In addition to products categorized as fine pastry, confectionery products are a very important source of fats and sugar where, apart from the dough, mainly fillings (especially those with fat, butter and whipping cream also containing more than 50% fat) and some products classified by Czech law as long-life baked goods (wafers and biscuits where fillings are also the main source of sugar and fat) play an important role (*Dostálová, Kadlec*, 2014). However, we do not consider these products as a target for reformulation. These are products intended for occasional consumption and it should be up to the consumer to decide how to consume them. However, the problem is the excessive consumption of these products by children, which is more the responsibility of the family and school education and training. We believe that a fundamental reformulation would not be appropriate in this case as the products would lose their character.

For the fine pastry products mentioned and described above, the situation is somewhat different. Historically, they are also products prepared for festive occasions, but thanks to massive purchasing power and a general surplus of food – globally speaking, the situation of our current civilization – the majority of these products have become almost daily consumables. This applies not only to adults but especially to children. Too frequent consumption of fine pastry products which, unfortunately, has become the norm even in the Czech Republic, is clearly contributing to the frequency of Type 2 diabetes, dyslipidemia, general manifestations of metabolic syndrome, and often even at a very low age *(Sluková, Skřivan, 2016)*.

Therefore, reformulations leading to a reduction in sugar and especially fat, or at least the substitution of saturated fats with more nutritional oils containing higher levels of polyenoic fatty acids or lipophilic vitamins and antioxidants, are more favourable in terms of nutrition.

Fats in the production of fine pastry

Fats are of great importance in the formation of the microstructure of the dough and soft inside of the products, and fundamentally affect the changes leading to aging manifested through the solidification of the product's soft inside. This role is mainly assumed by polar lipids even in low proportions of about 1-2% based on flour weight. Higher doses of fat also contribute to the slowing of product aging and affect the sensory quality of products. In terms of sensory quality, a higher proportion of fat in the dough improves the perception, yet this is undesirable in terms of the product energy content since fat has the highest energy value of the essential ingredients of food.

The dispersion of the fat components in the dough is important to achieve the greatest effect on the structure of the products and to retard aging. For this purpose, emulsifiers are used to significantly reduce the added fat content while maintaining similar effects on the structure *(Skřivan, Sluková, 2015)*.

From the point of view of health and nutrition, saturated fatty acids are especially problematic and trans unsaturated fatty acids (hereinafter "TFA") are deemed particularly undesirable. The increased intake of these fats is clearly undesirable and fine pastries are often characterized by their higher content. Unsaturated fatty acids are divided into monoenoic (one double bond) and polyenoic (with two or more double bonds). In nature, mainly *cis*-isomers of the double bond are present, except for milk fat and ruminant meat, where trans fatty acid isomers are also naturally present. The trans isomers of fatty acids can also occur during lipid oxidation and partial catalytic hydrogenation, in which fats of suitable consistency are formed from liquid oils. However, nowadays this practice is practically not used anymore and so the distribution of TFA is minimal (in margarines and frying fats) *(Brát, 2016; Sluková et al., 2016)*.

Consumers can still find TFA in various cheap fine pastries and long-life bakery products, chocolate icing (cocoa butter is replaced with partially hardened fats), vegetable-based substitutes for cream, whipped cream, etc. These fatty acids have been found to reduce membrane fluidity and increase oxidative stress, and alter cholesterol metabolism, thereby increasing the risk of cardiovascular disease (lowering HDL and increasing LDL), increasing the risk of **Type 2** diabetes and prostate, lung and colon cancer.

Depending on the type and nature of bakery products, virtually all types of fats are used - today, in particular, vegetable oils, hardened and emulsified fats (margarines), but sometimes also animal fats - butter or lard (for some exotic types of bakery products also beef or mutton tallow). The addition of fat improves the sensory properties of the bakery products, softens them and prolongs their durability. In particular, the addition of extra fat also requires the addition of emulsifiers, which are a common part of improvers in the bakers' sector *(Šedivý et al., 2015)*.

Despite the increased use of vegetable oils (especially rapeseed oil, which is nutritionally appropriate), regular margarine is undoubtedly one of the basic ingredients in the production of fine pastry. It is precisely hardened fats of this type that are used almost exclusively in the case of fine pastry made from puff and Danish doughs. Yet regular margarine is still one of the basic ingredients for yeast and crisp doughs. The margarine usually used for bakers' purposes contains 80% fat and 20% water, with 80% fat being the minimum. Some marketed margarine types also contain a higher percentage of fat. Margarines are produced by emulsifying a fat blend with water or milk or whey, resulting in a water-in-oil emulsion. The type of fat blend used and the method of production then affect the properties of the finished margarine. Nowadays, vegetable oils are most often used to produce margarines, which are widely marketed. They also often contain emulsifiers, dyes (beta-carotene), aromas (butter flavour), antioxidants and preservatives. The content of trans fatty acids in margarine is also now reported, where the lowest content is positive. Another characteristic closely monitored today is the content of palm or palm kernel oil, or RSPO certification (an RSPO certificate refers to palm oil that comes from sustainable sources and meets certain environmental criteria). The usual yeast dough margarine dose is between 10% and 20% of the amount of flour used. It is used not only for its organoleptic properties, such as the taste and texture of the dough, but also to extend shelf life *(Šedivý et al., 2016)*.

Possibilities for reducing fat and TFA content in baked goods

TFA content can vary greatly from product to product and even from brand to brand. For example, the content of TFA in the American type of bread and bakery products (usually richer in fat than is common in our country; a number of types of common American bakers' goods would already be classified as fine pastry in our country) has been found to be in the range 0.2–23.6% and in crackers 1.9-29.0%. In breads consumed in selected parts of Canada, TFA content was found to be 0.4-26.3% and in crackers up to 35.4% of total fatty acids. According to a number of studies, the main sources of TFA are bakery products (33-64% of the intake of these acids). This is due to the aforementioned daily, and sometimes even more frequent, consumption of some kinds of products we include in the bakery products category in our region (*Elias, Innis*, 2002). However, long-life bakery products, especially those with fillings and toppings, are a more significant source of TFA than breads and regular bakery products *(Santos et al., 2015)*.

In 1999, the reformulation of wafer recipes already lead to the replacement of partially hydrogenated fat in wafer fillings with non-hydrogenated fats. Since 2008, non-hydrogenated fats have been used not only in fillings but also in cocoa coatings. Partially hydrogenated fats have been shown to have a high TFA content, while oil and fully hydrogenated fat mixtures and non-hydrogenated fats showed low TFA levels *(Bačo, 2017)*.

The content of saturated fat in bakery products is less problematic. Where possible, it is recommended to replace the saturated fat in bakery products with fats with mono- and polyenoic fatty acids with a more beneficial effect on the blood lipid profile. The question, however, remains what is technologically possible and acceptable during dough processing.

Nutritional recommendations to reduce energy and saturated fats intake, especially TFA and cholesterol, are putting pressure on bakery products and confectionery producers as well as on other food production areas. As already mentioned, fat is a multifunctional ingredient in bakers' and confectionery products and therefore its substitution is not easy. When the fat content is reduced or completely omitted, adverse changes occur both in the mechanical processing of the dough and in the quality of the final product. Fat substitutes and fat mimetics are ingredients (carbohydrates and proteins) that can provide some functions of fat in foods, replacing fat in the recipe and reducing the energy value of the food. In particular, various types of fibre, vegetable gums, inulin, maltodextrins, polydextrose, modified starches, protein microparticles, modified protein concentrates (e.g. from soy or whey), protein blends and various emulsifiers are particularly suitable for making bread and bakery products *(American Dietetic Association, 2005)*.

While some fat substitutes have a positive effect on the structure of the bakery products, they adversely affect its sensory properties. Nor is the economic aspect non-negligible because fats commonly used in baking are often significantly cheaper than their nutritionally better substituents. The core of the majority of fat substitutes are various starch derivatives based on modified starches. Energy is reduced even when emulsifiers are used, which increase fat efficiency, thus allowing for reduced fat doses *(Příhoda et al., 2003)*.

Reformulations in this area are a major challenge. As can be seen, the fat contained in fine pastry products plays a significant, often even dominant, role in total daily fat intake, and its composition is often very nutritionally disadvantageous and substitution or composition adjustments are not yet advanced enough.

Sugar in cereal technology

The term sugar usually refers to common crystalline sucrose in bakery products, mainly sugar beet in this country. From a nutritional point of view, sugar beet does not differ from cane sugar, which is more common elsewhere in the world *(Příhoda et al., 2003)*.

The importance of added sugar lies primarily in refining the taste of the product. It is added to ordinary bakery products only at low doses or not at all. However, higher sugar additions are characteristic for fine pastry and confectionery products *(Šedivý et al., 2015)*.

Fine pastry made from yeast dough has 5–15% sugar in the recipe based on flour weight, while non-yeast types of pastry have a usual dose of up to 30% sugar in whipped and sponge cake recipes, sometimes more.

Sweet flavours can also be achieved by using other sweeteners, but their sweetening effect is not entirely identical. Only fructose monosaccharide shows higher sweetness than sucrose (Table 1), so less can be used in the recipe compared to sucrose *(Šedivý et al., 2016)*.

Table 1: Relative sweetness of selected sugars *(Čopíková et al., 1997)*

Sugar	Sweetness
Sucrose	1.0
Maltose	0.3–0.6
Lactose	0.2
Glucose	0.7–0.8
Fructose	1.4–1.6

A slight addition of sugar does not significantly affect the rheological properties of the dough, unlike comparable doses of salt. The importance of added sugar lies in two basic effects: partly in the technological sense, but mostly in the sensory impact. In the technological process of making yeast dough, the addition of sucrose provides a source of fermentable sugar for the yeast. Sucrose itself is not fermentable but can be hydrolysed by inverting to give fructose and glucose, which can be fermented. It has been shown that yeasts from common baker's yeast metabolize the added sucrose before they probably focus on metabolising maltose by altering the invertase to a maltase enzyme apparatus. Thus, a low sucrose dose in the dough is important to ensure a faster start-up of fermentation during the dough maturation. The addition of other fermentable sugars may also act similarly. Conversely, high doses of sucrose reduce yeast activity due to increased osmotic pressure. This means that doughs with a rich formula tend to mature much more slowly. The influence of sugar on the sensory properties of products is not only about achieving a sweet taste – sugar together with salt creates a complex impression of a full taste *(Příhoda et al., 2003)*.

Although fructose has the highest sweetness of all the sugars (Table 1), meaning that its dosage in a bakery products recipe can be reduced, the physiological significance should still be considered. Contrary to earlier thinking, fructose has a rather negative health effect in nutrition. Fructose is largely preferentially metabolised in the liver without the involvement of insulin and has no significant effect on blood glucose levels. It induces about half of insulin secretion compared to glucose – its glycaemic index is 20. However, since insulin cannot regulate the metabolism of fructose and its conversion to triose phosphates, fructose enters the glycolytic pathway without restriction and causes increased energy input. Triose phosphates formed from fructose can be converted to pyruvate and oxidized to CO_2 and H_2O or may be converted to fatty acids and initiate the lipogenesis process. The resulting lipid metabolites may lead to cardiovascular problems (e.g. myocardial infarction), or cause disorders in the transmission of the insulin signal and reduce glucose utilization. Many studies confirm that excessive fructose intake leads to dyslipidaemia and insulin resistance. Unlike glucose, fructose does not affect the secretion of insulin from the pancreas, so the use of fructose in the liver can be maintained even when the glucose content of the tissues is reduced (e.g. during fasting). Fructose also has no effect on leptin production from adipose tissue, and therefore has no effect on satiety, which may lead to subsequent higher food intake *(Di Bartolomeo, Van den Ende, 2015; O'Donnell, Kearsley, 2012)*.

Various types of syrups (starch syrups, glucose syrups, fructose and glucose-fructose syrups, high fructose corn syrups - HFCS) are sometimes supplied and processed for economic reasons *(Příhoda et al., 2003; Sluková et al., 2016)*.

Sugar alcohols (polyols) are often used in the manufacture of products for diabetics or energy-reduced products. Sugar alcohols are carbohydrate derivatives resulting from the reduction of a carbonyl group. Polyols are sweeteners, have a lower energy value than glucose and sucrose, and are used as sugar substitutes in various foods, beverages and the like. Some are poorly absorbed and then only metabolized by bacteria in the colon, which can cause laxative effects when consumed in large quantities. They are not cariogenic, which means they are not used by bacteria in the mouth. They are classified as additives and are therefore identified by using E numbers *(Sluková et al., 2016)*. They have low sweetness and so are supplemented with other sweeteners. Like fructose, they can perform well as a flavour filler. The perception of sweetness caused by these compounds is sometimes noticeably different from sucrose, and therefore they are used in mixtures to achieve the most natural sweetness possible. Saccharides commonly found in food, glucose, fructose, sucrose, lactose and honey are not used as sweeteners.

The combined use of synthetically produced sweeteners and sweeteners derived from natural sources is still one of the most widely used approaches to reducing sugar in food. However, for some foods such as bakery products, there is only minimal reduction of energy value through sugar substitutes *(Buttriss, 2017)*.

Possibilities for reducing the sugar content in baked goods

WHO Guidelines (2015) state that the amount of sugar consumed should not account for more than 10% of the daily energy intake, and there is a plan for EFSA to create an expert-approved limit for the daily intake of added sugars from all major sources by 2020. Replacing sugar will result in a reduction in both the short-term and long-term intake of energy, thereby slowing the increase in overweight, obesity and metabolic syndrome symptoms.

Research into childhood obesity has shown that sugary beverages are the most significant source of sugars in nutrition. They are followed by flavoured dairy products, breakfast cereals, bakery products (fine pastry and long-life products), then ice creams, chocolates and sweets. Among these products there are some for which reformulation is suitable due to their importance and frequency of consumption *(Monaco et al., 2018)*. However, the technological feasibility and acceptable sensory quality of the bakery products is another aspect.

In bakery products, the addition and combination of polyols such as sorbitol, maltitol, isomalt, xylitol, erythritol, polydextrose and the like can be used as a replacement for sucrose. However, the type and proportion of polyols or other sweeteners depend on the desired properties and type of the final product *(Martínez et al., 2015)*. Some sugar alcohols or combinations thereof may increase dough viscosity, water binding, affect crispness and crust colour, bread volume, may reduce water activity and inhibit retrogradation of starch aging *(O'Donnell, Kearsley, 2012)*. In the last decades of the 20th century, sweeteners such as saccharin, acesulfame and aspartame (often combinations thereof) were used as sugar substitutes. Due to increasing reservations about their overuse from both nutritional and sensory aspects, more attention has recently been paid to other sweeteners such as steviol glycosides and the like *(Struck et al., 2014)*.

Polydextrose can be used as a filler, the energy value of which is 4.2 kJ/g. About 40% of polydextrose is absorbed in the intestine and the remainder is fermented by intestinal bacteria or excreted unchanged. The addition of inulin can also serve as a substitute for fat in a long-life bakery products recipe. Bakery products with added fructooligosaccharides with a sweet taste was crunchier compared to bakery products with sucrose alone *(O'Donnell, Kearsley, 2012)*. *Ronda et al. (2004)* prepared sponge cake, leavened doughs and bakery products with additions of maltitol, mannitol, sorbitol, xylitol, isomaltose, oligofructose and polydextrose. Generally, the leavened cakes (fine pastry) prepared in this way were lighter in colour and lower in volume than cakes prepared with just sucrose alone. However, after baking, the cakes with sweeteners were softer and more pliant, except for the cakes with mannitol. *Schirmer et al. (2012)* investigated the effect of polydextrose addition on the change in physical properties of sponge cake. It has been shown that it is possible to prepare a cake with a similar texture and volume even with the 100% replacement of sucrose with polydextrose.

Muffins are a favourite bakery products not only abroad but in the Czech Republic, and reformulations of their recipes are very popular at both industrial and domestic scales. The original muffin formula contained mostly high doses of sugar and fat. A combination of inulin or polydextrose with steviol glycoside resulted in muffins which were sensorially comparable to muffins with the original sucrose dose *(Gao et al., 2016; Karp et al., 2016; Zahn et al., 2013)*. Also, the partial replacement of sucrose with steviol glycoside and the complete replacement of cocoa powder with cocoa fibre have been successfully tested *(Karp et al., 2017)*. Various doses of sorbitol, maltitol, isomalt and erythritol have also been tested as sugar substitutes in muffins *(Martínez-Cervera et al., 2014)*. The polyols increased the gelatinization temperature of starch, and erythritol especially adversely affected the rheological properties of the dough. In contrast, the addition of isomalt showed a positive effect on texture. It can be noted that for muffins or similar types of bakery products (sponge, whipped, chemically leavened), the polyols mentioned can be used as a partial replacement for sucrose *(Kim et al., 2014; Hao et al., 2016)*. *Zahn et al. (2013)* also partially replaced sucrose in muffins (about 1/3 of the original dose by weight was used) with steviol glycosides and various types of fibre (pea fibre, oat fibre, wheat fibre, wheat bran, apple pulp, cellulose, maltodextrin, polydextrose and inulin). An increase in the moisture content of the soft inside of the bakery products was observed, especially when using fibre components as a filler. Muffins with steviol glycoside had less volume. Inulin or polydextrose muffins were best rated; apple fibre and oat bran muffins were the least acceptable.

Manisha et al. (2012) observed changes in the properties of fine pastry in which sucrose was completely replaced by sorbitol and steviol glycosides. A higher sucrose content has been shown to increase dough viscosity while sorbitol alone reduced viscosity. Conversely, the combination of sorbitol with xanthan and polysorbate 60 (an emulsifier) increased dough viscosity and also improved dough homogeneity and porosity. After the addition of fibre, the nutritional value of the bakery products was increased, while the sensory value of the bakery products was evaluated very well in comparison with bakery products with sucrose.

Pareyt et al. (2010) investigated the properties of biscuits in which 30% of the recipe amount of sucrose was replaced with isolated arabinoxylooligosaccharides (AXOS). AXOS biscuits have been shown to have a comparable diameter and height to sucrose biscuits but have a darker colour. It is also necessary to emphasize the positive effect of AXOS as a prebiotic component. Reducing the sugar (sucrose) content in biscuits was accomplished by adding selected high-sweetness polyols and sweeteners. Biscuits prepared with sucralose (a synthetically-produced sucrose derivative containing 3 chlorine atoms per molecule), whey protein and margarine (which at the same time allowed a reduction in the flour content of the product), had favourable colour, texture and other sensory properties *(Marques et al., 2016)*.

However, simply reducing the sugar content of long-life bakery products often leads to undesirable technological effects resulting in a reduced crispness of these products *(Laguna et al., 2013a)*. The complete absence of sugar causes the completely undesirable intensification of the gluten structure in these products. In terms of processing conditions and technological effect, complete sugar substitution was achieved only by using maltitol *(Laguna et al., 2013b)*. Experiments using inulin as a partial sugar substitute have so far led to the conclusion that the substitution of up to around 25% of the original sugar content is realistic without a negative effect on the properties of the final product being observed. Similar results have been obtained for the addition of a mixture of steviol glycoside and maltodextrin as a replacement for sucrose in sweet bakery products typical in the Middle East *(Yazdi et al., 2017)*.

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Reformulation of food and meat products

Kameník J.

Food reformulation is defined as "changing the nutrient content of processed foods to reduce the content of certain substances such as sodium, saturated fatty acids, trans fatty acids or energy (kilojoules), or increasing the proportion of ingredients with a positive effect on the human body, such as fibre, fruits, vegetables, wholegrain cereals and unsaturated fatty acids" *(Neacsu et al., 2015)*.

Nowadays, experts and the general public agree that there are certain "healthy" food groups such as fruits and vegetables which can be eaten in larger doses, and then other foods, the consumption of which should be reduced (e.g. foodstuffs with increased sugar or fat content). To determine whether a food is beneficial to health, experts suggest a number of criteria such as energy density, fat character and sodium content *(Bucher et al., 2015)*. Labelling with nutritional values helps consumers orient themselves in their food choices and can also promote product reformulation and the development of healthier products.

Why do we need reformulated foods?

With the industrial revolution in the 19th century, machinery was introduced to produce, process, transport and store foods. This changed practices used for centuries, and development further intensified after World War II. In the 1970s, gigantic food corporations were established, resulting in a genuine revolution - industrial foods. Food producers have found ways to grow and produce as cheaply and efficiently as possible what people have liked to eat for thousands of years: fat, starch, sugar and salt. The result of their ingenuity has been a surplus of cheap, calorie-rich food *(Lieberman, 2016)*.

As many processed foods contain high levels of "unhealthy" nutrients such as sodium, hydrogenated fats, sugar and saturated fatty acids, consumption of these substances by consumers has exceeded the maximum levels recommended by the WHO *(Sleator, Hill, 2007)*. In the United States, 70% of the population over 1 year of age consume too much sugar, and in the case of sodium, a whole 89% of people exceed the recommended daily allowance *(van Langeveld et al., 2017)*. Combined with limited physical activity and a sedentary lifestyle, overweight and obesity *(Sleator, Hill, 2007)*, the associated metabolic diseases such as Type 2 diabetes, cardiovascular disease and cancers of the reproductive organs have increased considerably *(Lieberman, 2016)*. Hence there have been campaigns in Europe in recent years to promote a diet with a "healthy" potential *(Marotta et al., 2014)*. Food reformulation is one such activity.

Reformulated foods may enjoy increased consumer interest as there is growing public interest in eating with a positive impact on health. On the other hand, the failure rate of innovative foods launched to market is known to be high. It is therefore imperative to understand and consider consumer requirements at an early stage in the development of new or reformulated products *(Shan et al., 2017)*. The consumption of reformulated foods is influenced both by product-related factors (e.g. sensory properties, processing technology) and by consumer-related factors such as psychological influences, demographic characteristics and food selection habits. Theoretical models of food choice suggest that consumers' beliefs and opinions about food play a key role in this choice. Individual opinions about food are created based on taste, naturalness, preparation and consumption convenience, and the influence on health *(Bucher et al., 2015)*.

Reformulating food in meat processing

In the field of processed meats, i.e. in the group of meat preparations and meat products, the following modifications are concerned with regard to reformulations:

1. reducing the salt and/or fat content;
2. enriching products with ingredients with a positive effect on health (e.g. omega-3 fatty acids, probiotics, vitamins, fibre);
3. reducing or completely replacing chemical additives such as nitrites *(Shan et al., 2017)*.

Since there has recently been a lot of discussion about the need to reduce salt intake in the EU and other developed countries, we are first going to focus on the issue of salt in meat products.

Salt in food

Sodium plays an important role in the human body and is an irreplaceable chemical element *(Mitchell et al., 2013)*. For example, it maintains the potential of cell membranes, contributes to the absorption of nutrients in the small intestine, regulates the volume of extracellular fluid and thus also affects blood volume and pressure. About ninety percent of the body's sodium comes from edible salt in the human diet *(Kloss et al., 2015)*. Worldwide, however, the average daily salt intake is much higher than the

WHO's recommended daily dose (<5 g/person). Excessive salt intake in the diet contributes to the development of cardiovascular diseases as it increases blood pressure with age *(Zandstra et al., 2016)*. The recommended salt intake corresponds to sodium consumption of less than 2 g per day, while physiological needs are estimated at 200-500 mg/person per day *(Silow et al., 2016)*.

Foods that put most strain on humans through high sodium content include bakers' goods, processed meat (meat products and meat oven-ready meals), cheeses and some dairy products. It is estimated that industrially processed foods account for about 75% of the sodium intake in developed countries *(Aaslyng et al., 2014, Mhurchu et al., 2011)*. Many of these foods have hidden salts, with consumers unaware that such products may contain a higher proportion of sodium *(Downs et al., 2015)*. In these cases, it is appropriate to encourage the processing industry to reduce the salt content of foods by setting targeted or standard salt levels in certain categories of food that producers should then follow.

The overall intake of salt (and thus sodium) in human nutrition generally comes from three sources:

1. commercially produced foods (e.g. bread and bakery products, soups, restaurant meals, meat products);
2. natural content in food;
3. addition of salt by the consumer during cooking and/or during meals at the table (discretionary salt).

The proportion of major salt sources in the human diet varies by global region. In Japan, for example, soy sauce is the main salt donator. In China, it is the addition of salt during cooking, and industrially produced foods contribute about 71% in the US and up to 95% in the United Kingdom. Very little is known about salt added by the consumer when cooking or at the table. It is estimated that this salt may represent up to 30% of the total salt intake. However, the variability between nations or countries is considerable – in the UK it is only about 5%, but in China it is up to 78%. One recent international study found that nearly a quarter of respondents admitted they often add salt to food without tasting it beforehand *(Zandstra et al., 2016)*. Knowledge in these areas can help us understand consumer habits and better target efforts to reduce salt levels in human nutrition. The preferred level of sodium in foods depends on the amount of sodium consumed. Over a period of time, this amount of sodium can be reduced by lowering its level in the diet. Reducing sodium intake to 1,600 mg per day resulted in an increase in the salty taste perception threshold and a decrease in interest in sodium-rich foods *(Mitchell et al., 2013)*.

In particular, if there is to be a significant reduction in salt intake in the human diet, a shift in two key areas is required, namely commercial food and consumer behaviour *(Zandstra et al., 2016)*. To implement targeted salt levels in foods, *Downs et al. (2015)* recommend a multi-step approach:

1. identify the major sources of salt in human nutrition
2. choose foods for the implementation of target salt levels
3. determine the target salt levels in these foods
4. identify stakeholder engagement strategies
5. prepare appropriate monitoring methods.

It is logical that many countries have adopted strategies to reduce the consumption of sodium due to the high economic strain that its intake puts on the population of developed countries *(Woodward et al., 2012)*. The United Kingdom was the first country to introduce large-scale target salt levels, and between 2003 and 2011 there was a decrease in salt consumption of 1.4 g/person per day *(Downs et al., 2015)*.

Salt and meat products

Meat products are also at the centre of attention of the professional as well as the general public in terms of dietary salt intake. Reformulation of this category of food is therefore mainly aimed at reducing the content of salt. There are a number of papers available in which the authors describe the results of substituting table salt, i.e. NaCl, with other salts, most often containing potassium, magnesium or calcium *(Lorenzo et al., 2015; Horita et al., 2014; Paulsen et al., 2014)*. Reducing salt levels in their products is a great challenge for food processors, as salt in food (including meat products and oven-ready meals) also plays a functional role in texture and preservation *(Zandstra et al., 2016; Tobin et al., 2012)*. The meat product formula requires a certain concentration of NaCl, since edible salt promotes the dissolution of myofibrillary proteins, thereby determining the binding of the product and the stability of the fat component *(Horita et al., 2011)*.

In Ireland, Tobin et al. (2012) tested sausages made from beef and pork with a salt content of 1.0, 1.5, 2.0, 2.5 and 3.0%. The sausages used cellulose casings. The samples with a salt content of 2.5% were best perceived by the evaluators. The sausages with a salt content of 1.5% or less were assessed more negatively by the evaluators. Based on these results, the authors argue that in the case of sausages, salt-reduced products cannot be successfully prepared from the marketing point of view without using a substitution for the reduced salt content *(Tobin et al., 2012)*.

A mixture of sodium, potassium, magnesium and calcium chlorides is most frequently used as a partial or complete replacement for edible salt (i.e. NaCl) *(Triki et al., 2013)*. *Horita et al. (2011)* tested the partial replacement of

NaCl (50% or 75%) with a mixture of the above chlorides in mortadella salami. A total of 7 samples of this salami were prepared (F1: 2% NaCl as control, F2: 1% NaCl, 0.5% KCl and 0.5% $CaCl_2$; F3: 1% NaCl, 0.5% KCl and 0.5% $MgCl_2$; F4: 0.5% NaCl, 1% KCl and 0.5% $CaCl_2$; F5: 0.5% NaCl, 1% KCl and 0.5% $MgCl_2$; F6: 1% NaCl and 1% KCl; F7: 1% NaCl). The weakest emulsion stability was found with F4 and F2, i.e. the $CaCl_2$-containing sausages. In fact, calcium ions reduce the solubility of myofibrillary proteins. The mortadella samples with calcium chloride also showed the lowest pH. The most stable in terms of emulsions formed were F1 and F6, i.e. those with the addition of only monovalent cations (sodium and/or potassium). The samples with $MgCl_2$ content did not differ from F7 prepared with only 1% NaCl in terms of emulsion stability. The appearance, aroma and texture of the products showed only a statistically insignificant difference ($p> 0.05$) in sensory evaluation compared to the control (2% NaCl). However, there were differences in taste, with the evaluators mostly rejecting F5 (0.5% NaCl, 1% KCl, 0.5% $MgCl_2$), followed by F3, F4 and F6. These samples differed significantly from the control F1 ($p < 0.05$). In contrast, F2 (1% NaCl, 0.5% KCl and 0.5% CaCl2) and F7 (1% NaCl) did not differ significantly from the control sample in terms of taste.

It is interesting that in a study by *Hority et al. (2011)* the evaluators did not find significant differences in mortadella taste when made with 1% or 2% salt. This means that the taste of meat products is also influenced by factors other than sodium chloride. Similarly, the work of *Kameník et al. (2017)* showed that there were no statistically significant correlation coefficients between salt content and sensory indicators. A total of 133 heat-treated meat products of Czech and German origin were analysed in this study. The parameters listed in Table 2 were determined in relation to salt content (determined on the basis of sodium level) and selected sensory properties.

Table 2: Correlation coefficients between salt content and sensory properties of heat--treated meat products *(Kameník et al., 2017)*

Sensory characteristics	Correlation coefficients
Cut surface appearance	0.06
Colour	0.13
Matrix	0.19*
Odour	-0.06
Consistence	-0.11
Texture	-0.18*
Saltiness	-0.08
Taste	-0.02
Overall acceptance	-0.07

**p<0.05*

Triki et al. (2013) tested the partial replacement of edible salt in merguez sausage. While 1.4% NaCl was used in the traditional recipe, 0.7% of the edible salt was replaced with a mixture of KCl (0.35%), $CaCl_2$ (0.20%) and $MgCl_2$ (0.15%) in sodium-reduced samples. Thanks to the change in the recipe, the proportion of sodium in the finished products was reduced from 630.7-649.8 mg/100 g to 386.3-412.0 mg/100 g, i.e. by more than 36%. No statistically significant differences were found in the juiciness, stiffness and overall acceptability of the merguez samples between those containing 1.4% edible salt and those with the chloride mixture. The authors concluded from the results of the sensory analysis that the partial replacement of sodium chloride with a mixture of potassium, calcium and magnesium chlorides together with increased addition of spices is possible without a negative effect on the taste of the final products. However, sodium-reduced products showed higher losses when cooked ($p < 0.05$) compared to the samples with 1.4% NaCl *(Triki et al., 2013)*. The so-called breakfast sausages, also belonging in the oven-ready meals group, are popular in the British Isles. Tobin et al. (2013) conducted detailed testing with salt proportions of 0.80 to 2.40%. The most acceptable for consumers were products with 1.40% edible salt.

Alves et al. (2017) tested the possible substitution of 50% NaCl with potassium chloride in finely ground bologna sausages. Four samples were prepared with edible salt replaced with KCl along with the addition of lysine (Lys) and/or liquid smoke (LS): sample 1:1.25% NaCl and 1.25% KCl; sample 2: 1.25% NaCl, 1.25% KCl and 1.0% Lys; sample 3: 1.25% NaCl, 1.25% KCl, 1.0% Lys and 0.1% LS; sample 4: 1.25% NaCl, 1.25% KCl and 0.1% LS. The control sample was made with 2.5% NaCl. The product was filled into plastic containers with a diameter of 40 mm and heated to reach an internal temperature of 72 °C. Collagen casings with the same diameter were also filled with the product to test for heat loss.

The replacement of 50% NaCl with potassium chloride did not show statistically significant differences ($p > 0.05$) in losses during cooking or in emulsion stability, instrumental colour parameters (CIEL*a*b*) or stiffness of the final salamis. The sodium content was reduced from 1,375 mg/100 g in the control sample to 655-672 mg/100 g in the tested samples through the replacement of the edible salt with KCl. The authors stated that the technological properties of the product with 1.25% KCl and 1.25% NaCl were the same as with 2.5% NaCl.

In sensory testing, however, the evaluators perceived the taste of the sample with KCl and NaCl as astringent, metallic, bitter and strange. After the addition of lysine, the taste and aroma were evaluated as characteristic. The liquid smoke samples showed smoky to slightly acidic flavours. The samples with the partial replacement of NaCl with potassium chloride and with added lysine and/or liquid smoke differed only statistically insignificantly from the control sample (2.5% NaCl) ($p > 0.05$). Both lysine and liquid smoke were able to mask the taste deficiencies caused by the addition of KCl *(Alves et al., 2017)*. In 1996, Gou and his colleagues published a study about the partial replacement of NaCl with potassium chloride in long-life meat products *(Gou et al., 1996)*. The evaluators noticed a bitter taste in the fermented salami already when 30% of the edible salt was replaced with KCl, but the intensity of this deviation was considered insignificant up to a substitution level of 50%. Based on the results, the authors stated that substitution of up to 40% of NaCl with potassium chloride is possible without the quality parameters of the final products deteriorating.

Based on studies carried out by various authors in different countries and on various meat products or oven-ready products, it can be stated that the edible salt content, or sodium, may usually be reduced up to a proportion of 30-40% through replacement with potassium chloride or a chloride mixture (KCl, $CaCl_2$, $MgCl_2$). However, increasing potassium intake may, under certain conditions, have an adverse effect on health *(Steffensen et al., 2018)*. The UK's National Institute for Health and Care Excellence discourages the use of potassium and other substitutes as sodium chloride replacement *(NICE, 2010)*. There are two reasons for this: to help consumers consume foods with a lower salt content and to avoid additives that may have other potentially adverse health effects.

The United Kingdom Expert Group on Vitamins and Minerals (EVM) has published two reports containing discussions on potassium toxicity *(Steffensen et al., 2018)*. Cases of acute human poisoning have been associated with a high intake of potassium chloride from food

Figure 5: On the one hand, the substitution of sodium chloride with potassium chloride can reduce sodium intake, while on the other it can pose a danger to certain sensitive population groups.

supplements or sodium chloride substitutes. The described effects included heart failure, cyanosis and cardiac arrest. Adverse effects after subchronic and chronic potassium ingestion were gastrointestinal toxicity accompanied by abdominal pain, nausea and vomiting, diarrhoea and ulceration in the oesophagus, stomach, duodenum and ileum. Potassium in sodium chloride substitutes also caused tightness of the chest, shortness of breath and heart failure. The EVM said there was not enough information to determine a safe upper limit for potassium intake, but using a supplement of 3.7 g of potassium a day in a normal diet has no obvious adverse effects.

Similarly, the EFSA reports a safe dose of 3.0 g potassium/day in addition to potassium intake in the daily diet *(EFSA, 2005)*. However, the same study describes adverse changes in cardiac activity and peripheral nervous system in healthy subjects with single doses of 5-7 g.

As groups of persons sensitive to increased potassium intake, *Steffensen et al. (2018)* list patients with renal failure, heart failure, diabetes, children under 1 year of age, seniors over 85 years of age and people taking medications that interfere with the potassium balance in the body. Each group has different levels of sensitivity to potassium. Increasing the potassium content of some industrially produced foods that are not a naturally rich source of this element can complicate medical nutrition recommendations for these risk groups. For example, patients with severe renal failure are particularly susceptible to potassium intake from food and are recommended to consume not more than 1.5 g of potassium per day *(Steffensen et al., 2018)*. People with renal failure have reduced potassium excretion capacity. Higher samples of potassium in the diet in this group are associated with elevated levels of potassium in the blood, called hyperkalaemia. Under physiological conditions (for healthy people), this blood plasma level is maintained at 3.5-5.5 mmol/l (135-195 mg/l; *EFSA, 2016*). Patients with heart failure take drugs (e.g. ACE inhibitors, beta-blockers, aldosterone antagonists etc.) that potentially increase blood potassium levels and may also lead to hyperkalaemia. In heart muscle cells, potassium maintains heart rhythm. Therefore fluctuations in the level of this element can lead to cardiac arrhythmias *(Steffensen et al., 2018)*.

Attention should also be paid to the variability in the salt (sodium) content of the same products across producers. For example, in Czech meat products *Kameník et al. (2017)* found average sodium levels (according to the producers) of 558.0-1308.0 mg Na/100 g. Using the conversion coefficient of 2.5 according to Regulation (EU) No 1169/2011, the values corresponded to a proportion of edible salt in meat products of 1.40-3.27%. *Ruusunen and Puolanne (2005)* have shown sodium chloride levels in Finnish meat products of 1.6-2.2%, in ham of 1.9-2.7%. In an analysis of Dutch foods, *Capuano et al.* (2013) detected average sodium values for similar types of meat products between 759 (sausages) and 1050 (pork shoulder ham) mg/100 g, which corresponded to an average salt content of 1.93-2.66%. *Ruusunen and Puolanne (2005)* propose focusing on products that exceed the averages measured in the individual types or categories of meat products to reduce the salt (sodium) burden on consumers. If the above-average salt values were reduced to average values (which, from a technological or sensory point of view, would not be a problem), the total salt proportion in a given product or meat product category would be lower.

Salt content and shelf life of meat products

Salt has always been used as an ingredient that enhances flavour but also prolonged the shelf life of meat and other foods *(Burgess et al., 2016; Bidlas, Lambert, 2008)*. The principle of the preservative effect is to increase the osmotic pressure *(Gutierrez et al., 1995)*. This reduces the water activity in the food, with a consequent bacteriostatic effect *(Duranton et al., 2012)*. The internal osmotic pressure in a bacterial cell is higher than in the surrounding medium *(Gutierrez et al., 1995)*. The result is pressure acting from within the bacterial cell against the cell wall, referred to as turgor. The bacterial cell must be able to maintain the turgor irrespective of differences in the external osmotic pressure. The response of microorganisms to osmotic stress includes both physiological changes and variations in gene expression *(Gandhi, Chikindas, 2002)*. This is referred to as osmoadaptation.

Principle of the NaCl preservative effect in the food environment and the bacterial cell reaction

The universal response to temporary turgor loss after hyperosmotic shock is the accumulation of solutes in the cytoplasm. As a result, the internal osmotic pressure, which can restore the turgor, increases. Non-ionic substances are preferred because many enzymes lose their activity in the presence of high salt concentrations *(Gutierrez et al., 1995)*. Bacteria capable of growing in a high-osmotic-pressure environment have developed the ability to accumulate high cytoplasmic levels of a particular class of solutes that do not seriously interfere with the functionality of cytoplasmic enzymes and are referred to as compatible substances. The controlled accumulation of compatible substances is therefore a major factor in the adaptive response of bacterial cells to osmotic stress.

Compatible substances can either be transported to cells from the external environment or synthesized de novo in the cytoplasm. There are differences in how bacteria tolerate the high osmotic pressure of the external environment.

Gram-negative bacteria show lower resistance and hence higher sensitivity to higher salt concentrations in the environment *(Burgess et al., 2017). Salam and Samejima (2004)* found that the addition of NaCl suppressed the growth of the *Enterobacteriaceae* bacteria strain in tests with ground beef after 21 days of storage at 2 °C (3.22 log CTU/g) compared to the untreated control (7.39 log CTU/g). In contrast, there was almost no difference in the case of lactic acid bacteria (LAB) (control 8.36 log CFU/g, addition of NaCl 7.83 log CFU/g).

Salt addition reduced the quantity of aerobic mesophilic bacteria in pork by about 1 log CFU/g at a concentration of 1.5% and 2 log CFU/g at 3.0% compared to a control at day 0 *(Duranton et al., 2012)*. The higher concentration was able to maintain this difference even on day 6 of the trial. However, this bacteriostatic effect did not appear on day 12, when the number of aerobic mesophilic bacteria reached approximately the same level of 9 log CFU/g in all samples. In the case of the *Enterobacteriaceae* strain, at 3% NaCl concentration a reduction of 2.2 log CFU/g on day 0 was observed, and 2.7 log CFU/g on day 6. However, on day 12 the bacteria level was again about 8 log CFU/g in all samples. Over time, gram-negative bacteria, initially sensitive, can build up defence mechanisms to overcome osmotic stress.

Gram-positive bacteria capable of growing in an osmotically-stressed environment include *Listeria monocytogenes* and *Staphylococcus aureus*. *S. aureus* it is a halotolerant bacterium capable of growing at aw values up to 0.86 (equivalent to 3.5M NaCl). Osmoprotective agents for this bacterium are choline, taurine, proline, and betaine. The degree of accumulation depends on the degree of osmotic stress. The most effective osmoprotective agent for *S. aureus* is betaine *(Gutierrez et al., 1995)*.

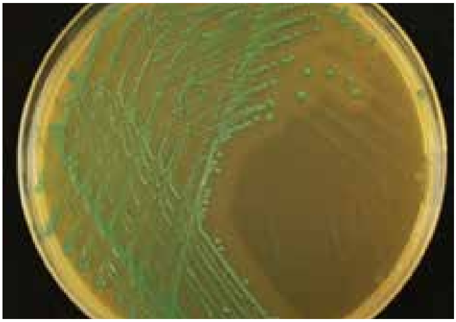

Figure 5: *Listeria monocytogenes* possesses the ability to defend against high environment osmolarity (in the picture, a colony on ALOA agar, photo by MVDr. Šárka Bursová, Ph.D.

One of the mechanisms used by *L. monocytogenes* for high environment salt tolerance is a change in gene expression leading to increased or decreased synthesis of various proteins. Salt shock (Ssp) and stress acclimation (Sap) proteins have been identified. If there are no protective agents (such as betaine, carnitine, etc.) in the external environment, the bacterial cells synthesize the Ctc protein in response to high osmolarity. The ctc gene responsible for its production is dependent on the sigma factor σB. This factor is an important component in the cell response of *L. monocytogenes* to stress caused by adverse external conditions. The extent to which bacteria depend on the sigma factor σB in their response to stress conditions differs between serotypes *(Gandghi, Chikindas, 2007)*.

Product preservation/safety when reducing edible salt content

In the reformulation of oven-ready meat and other meat products, two alternatives are considered in connection with the reduction of sodium (edible salt) - the first is to lower the salt level to a certain level considering technological and sensory limits. The second consists in partially replacing sodium chloride with other chlorides. Potassium chloride is the most important in this respect, as discussed above.

Since NaCl has a preservative effect and thus affects the growth of bacteria, there is a theoretical consideration regarding whether limiting sodium levels can have a negative impact on the safety of reformulated foods *(Sleator, Hill, 2007)* or their shelf life.

From the point of view of replacing edible salt with potassium chloride, this change should have no impact on the microflora present. As *Bidlas and Lambert (2008)* found when testing the strains *Aeromonas hydrophila, Enterobacter* (Cronobacter) *sakazakii, Shigella flexneri, Yersinia enterocolitica and Staphylococcus aureus*, potassium chloride has an antimicrobial effect (when calculated on a molar basis) equivalent to NaCl. The same results have also been reported by *Hystead et al. (2013*) in the case of survival testing of the *L. monocytogenes* strain in cheddar cheese. Thus, from a microbial point of view, the substitution of edible salt with KCl does not impact shelf life, which has also been shown through studies on meat products *(Alves et al., 2017)*.

From the point of view of food safety, we cannot simply conclude that a reduction in salt content in meat preparations or meat products automatically increases the risk of the survival or growth (multiplication) of foodborne agents in the product. Conversely, the more salt the less risk of bacteria. It is true that the ability to survive and/or grow under conditions of osmotic stress (which arises after the addition of edible salt) contributes to the persistence of pathogens in food *(Burgess et al., 2016)*. However, it is also necessary to consider that exposure to osmotic stress within the food chain may result in cross-protection from other emerging stresses (e.g. heat treatment) or during passage through the digestive tract. In the case of *L. monocytogenes* bacteria, this is the ability to grow at low temperatures or to increase resistance to bile salts. Scientific literature describes a case where the heating of *L. monocytogenes* cells in a 9% NaCl environment lead to an 8-fold increase in thermal resistance compared to a medium with no salt addition *(Burgess et al., 2016)*.

In the case of many foodborne agents (salmonella, STEC, *L. monocytogenes*), there are known cases of their survival in foods with lower water activity (<0.95). From this it is clear that reducing salt level in meat products to technological and sensory limits of about 1.7% does not affect the survival or multiplication of the foodborne agents. In other words, these bacteria would survive and multiply equally well in a salt concentration of 2.0-2.5% as they have developed adaptation mechanisms to survive osmotic stress.

Other factors are more important for the safety of meat preparations or meat products, namely the microbiological quality of the raw material, especially fresh meat, as well as other more severe barriers to the bacteria present (high temperature and time of action in the event of heat treatment, pH value, presence of starter cultures and the resulting aw for dry fermented sausages etc.). In food processing, salt only provides a weak obstacle and also only for a limited time. Its importance lies in its role in blocking the multiplication of gram-negative bacteria, which are capable of relatively rapidly causing the spoilage of meat, such as *Pseudomonas* bacteria.

The addition of salt to meat products affects the water activity value as follows: If the fresh meat has an aw value between 0.990 and 0.980, the aw values decreased to 0.969, 0.959 and 0.950 after additions of 2.5, 3.5 and 4.5% of a nitrite saline mixture in the production of long-life fermented salami *(Klettner et al., 1999)*. Yet, from

Table 3: Parameters limiting the growth of selected foodborne agents
(source: Gareis et al., 2010)

Gram-negative bacteria	Temperature (°C)	Water activity aw	pH value
Salmonella enterica	5.2–46	0.94	4.2–9.5
Campylobacter jejuni	30–47	0.98	4.9–9.0
Escherichia coli O157:H7	8–46	0.95	4.2–9.5
Shigella sonnei	6–47	0.95	4.8–9.0
Yersinia enterocolitica	-1.3–42	0.94	4.2–10.0
Gram-positive bacteria			
Listeria monocytogenes	0–43	0.89	4.5–9.0
Staphylococcus aureus	8–45	0.84	4.5–9.3
Clostridium botulinum, proteolytické typy A, B, F	10–48	0.94	4.6–9.0
Clostridium botulinum, neproteolytické typy B, E, F	3.3–45	0.97	5.0–9.0
Bacillus cereus	5–50	0.91	4.4–9.3

Table 3 it is clear that most pathogens are still growing at a value of 0.95. This corresponds to approximately 4.5% of salt. Reducing the addition of salt to levels of 2.0% or less still results in water activity of 0.98-0.97.

According to *Aaslyng et al. (2014)*, the proportion of salt in cooked sausages can be reduced from 2.2 to 1.7% and in cooked hams from 2.3% to 1.8% without compromising the shelf-life or safety of the final products.

Reformulating meat products and fat

Fat in food is an important source of energy, contains essential fatty acids and dissolves important vitamins *(Ham, Bertram, 2017)*. Fat in the human diet should ideally contribute 15-30% of the energy intake *(Jiménez-Colmenero, 2007)*. Yet there is usually more fat level in the diet of modern humans, and the proportion of lipids in food intake is about 36-40% *(Jiménez-Colmenero et al., 2012)*. *Dominguez et al. (2017)* described the proportion of fats in the energy intake at around 33% in a group of people consuming less than 3 portions of red meat a week, while the proportion of fats increased to 38% when the number of servings was more than 7 a week. *Schmidt et al. (2015*) stated that the share of fat in the energy intake in a group of meat consumers was about 32.0%, for vegetarians it was 31.5% and for vegans 30.4%.

Fatty acids - an important part of food fats

Most fat from food, including meat, is chemically called neutral lipids - triacylglycerols, i.e. fatty acid esters of glycerol *(Webb, O'Neill, 2008)*. The nature of the fat is determined by the presence of individual fatty acids (hereinafter "FA"), namely the length of their chain and the presence or absence of double bonds in the molecule. The main feature of the chemical structure of FA is the presence of a hydrophilic carboxyl group at one end and a long hydrophobic hydrocarbon chain ending with a methyl group *(de Oliveira et al., 2017)*.

In general, a distinction is made between saturated FA (hereinafter SFA) and unsaturated FA. Unsaturated FA contain only one double bond in their molecules - and in literature are also referred to as monoenoic FA (MFA) - or two or more bonds, in which case they are polyenoic FA (hereinafter "PFA"). The FA of this latter group are further distinguished by the position of the first double bond in the hydrocarbon chain. If the first double bond is between the 3rd and 4th carbon (calculated from the terminal methyl group), it is a FA of the n-3 series (omega-3), if the first double bond is between the 6th and 7th carbon, it is a FA of the n-6 series (omega-6); or the double bond can start between the 9th and the 10th carbon, in which case it is n-9 FA. Two essential FA are represented in the PFA group, namely linoleic acid (n-6) and alpha-linolenic acid (n-3).

The nutritional recommendations for the intake of specific FA show a share of energy intake of no more than 10% for SFA, 6-10% for PFA and 10-15% for MFA. The recommended ratio between PFA and SFA in nutrition should be between 0.4 and 1.0, and between n-6/n-3 FA should not exceed 4.0 *(Jiménez-Colmenero, 2007)*. According to *Stark et al. (2016)*, in ancient times the n-6/n-3 FA ratio in the human diet was between 2-3:1, while now it is 10-20:1.

The current nutrition of the population in industrialized countries is too rich in energy, yet on the other hand contains too little of the important components, including n-3 FA. Efforts to reformulate industrially produced food in EU countries as well as in other developed countries are attempts to improve this situation. There is also interest in reformulation in the processed meats category, i.e. meat products and oven-ready meat preparations.

Changes in the proportion and characteristics of fat in meat products could improve their nutritional value. Consumers' reluctance to change their nutritional habits suggests that there is a significant potential market for frequently consumed products (e.g. meat products/oven-ready meat preparations) and their reformulation *(Jiménez-Colmenero, 2007)*.

Table 4: Fatty acid profiles in common fats and vegetable oils
(source: Stortz et al., 2012)

Type of fat	saturated (%)	monounsaturated (%)	polyunsaturated (%)
Canola oil	6	62	32
Soybean oil	15	23	61
Linseed oil	9	17	74
Milk fat	62	31	2
Cocoa butter	60	35	1
Tallow	37	59	2
Lard	39	49	11

Reformulation of meat products/ oven-ready meat preparations in terms of fat content

The reformulation of meat products with regard to fat content is currently proceeding in two directions. The easier way is to simply reduce the proportion of fat in the final product. The second is to substitute (usually partially and in varying degrees) naturally used animal fat (lard or beef tallow) with another fat whose properties are more in line with health recommendations *(Keenan et al., 2015)*. There are many sources of fat that can be used for this purpose, and include plants and seafood *(Jiménez-Colmenero, 2007)*.

However, any change in the fat component of meat products must be done with great care. Fat affects a number of qualitative properties of meat and meat products *(Brewer, 2012)*. It contributes to their texture and taste and also increases the feeling of satiety after meals *(Ham, Bertram, 2017)*. More than half the volatile substances identified in heat-treated meat originate from lipids, which serve as the primary source of flavour compounds *(Brewer, 2012)*.

For these reasons, a reduction of fat in a recipe is usually accompanied by undesirable effects related to technological and texture properties (higher heat treatment losses, texture deterioration). One strategy used to reduce the fat content of meat products is based on fat replacement with ingredients such as vegetable or animal proteins, hydrocolloids or fibre in order to obtain the desired texture, to obtain certain functional properties or to affect the composition of the final product *(Ham, Bertram, 2017)*.

Fat substitutes are generally classified according to their composition. They can be protein-based, fat-based or carbohydrate-based *(Brewer, 2012; Samapundo et al., 2015)*. In principle, the product-processing technology does not change. When producers seek to reduce the proportion of fat in their final products, polysaccharide-based materials are clearly the most widely used fat substitutes.

Replacing natural fat (i.e. lard or beef tallow) in processed meats with a fat component can be applied in the form of liquid oil or solid fat *(Jiménez-Colmenero, 2007)*. Compared to standard carcass fat, newly used materials (of plant or fish origin) have different physicochemical properties. Therefore, the meat processing conditions must be adapted so that the reformulated products have the desired quality and do not differ too much from the standard products on the market.

Procedures for using plant or fish fats in meat products include the direct application of fat components, incorporation in encapsulated form or in the form of stabilized emulsions (pre-emulsified oils) or the use of structured edible oils. Another possibility is the direct use of plant ingredients with a higher fat content.

Direct application of liquid oils

Oils are liquid at room temperature, and even in refrigerators, so their use in some meat products can cause technological difficulties. In principle, oils must be used in the form of stable oil droplets that do not bond to each other during cooking or during product processing *(Jiménez-Colmenero, 2007)*. This would reduce the quality of the final products and also the yield. Oils are also more susceptible to oxidation due to the higher content of unsaturated FA.

Oil was added to the whole muscle meat products as a micro-spray. Oils are applied directly during the preparation of beef burgers. For finely ground emulsion-type meat products, the addition of oil at the end of the grinding process is recommended. Oil is used to increase viscosity at lower temperatures. For example, olive oil at -6 °C to replace 5% of lard in low-fat sausages *(Jiménez-Colmenero, 2007)*.

Application of pre-emulsified oils

In general, this method is used for oils that are difficult to stabilize. It is an oil-in-water emulsion with an emulsifier, most often a non-meat protein *(Youssef, Barbut, 2011)*. It is prepared before the actual preparation of the meat product and is added as a fat component during the actual processing of the product.

Oils are stabilized/immobilized in the protein structure *(Jiménez-Colmenero, 2007)*. This reduces the risk of separation of the oil component from the meat product during the processing, storage and consumption processes. In addition to stability, lipid sensitivity to oxidation is also reduced. The process for preparing pre-emulsified oils can be as follows: 8 parts hot water (50-60 °C) are mixed with one part sodium caseinate or soy isolate for 2 minutes. The mixture is emulsified with 10 parts oil for another 3 minutes and then cooled.

Youssef and Barbut (2011) tested 12 samples of shredded lean beef (19.6% protein, 5.9% fat) with added beef tallow (10%, 17.5% or 25%), or low-erucic acid rapeseed (canola) oil (10%, 17.5% or 25%), or pre-emulsified canola oil (10% or 17.5%), with the use of sodium caseinate, soy isolate or whey protein isolate. For the pre-emulsified fat, a protein:canola oil:water ratio of 0.5:8:8 was used.

The highest losses through heat treatment (at 72 °C) were found with the 10% beef tallow samples, the lowest with the 17.5% pre-emulsified oils prepared with soy or whey protein. In general, pre-emulsification of canola oil with soy or whey proteins helped stabilize the product and achieve lower heat treatment losses. The sodium caseinate pre-emulsified oil samples showed the same high losses as with the direct use of canola oil. The authors explained the insufficient effect of sodium caseinate through its inability to form a gel at the heat-treatment temperature (72 °C). Analysis of the texture profile revealed a decrease in the stiffness of the samples with decreasing fat content. This was probably due to increasing water levels, as water shows less compression resistance *(Youssef, Barbut, 2011)*. Replacing beef tallow in the described study with canola oil or pre-emulsified canola oil significantly increased stiffness. This was the result of the creation of much smaller canola oil fat droplets whose average area was only 1% compared to beef tallow fat droplets (63 vs. 6101 μm^2) for finely divided samples of 25% canola oil or 25% beef tallow. The larger surface area covered by proteins leads to higher binding and thus higher stiffness (higher resistance to compression).

The addition of canola oil or pre-emulsified oil instead of beef tallow caused an increase in the L* lightness value. The reason was again the higher surface of finer oil droplets, as they reflected more light *(Youssef, Barbut, 2011)*.

Delgado-Pando et al. (2011) tested the use of pre-emulsified oil to replace lard in sausages. The oil was applied as a mixture (44.4% olive oil, 37.9% linseed oil, 17.7% fish oil), while either sodium caseinate or soy isolate, or a mixture of soy isolate, microbial trans glutaminase enzyme and sodium caseinate were used for the emulsification. Single batches of sausages were prepared from 2.6 kg of meat, 0.5 kg of lard and 0.8 kg of water (control), while emulsions (0.8 kg) and water (0.5 kg) were used instead of lard for the samples tested. The sausages were kept for 41 days at 2 °C. Samples for analysis were taken on days 1, 13, 27 and 41.

Vegetable oil samples showed higher TBARS (thiobarbituric acid; $p < 0.05$) compared to the control. Although the authors also noted differences with regard to the presence of bacteria and biogenic amines, the reformulated fat sausages did not pose increased microbial risk compared to the control sample.

The stabilized emulsion form was also used to replace 25% of lard in Spanish long-life fermented salami *(Valencia et al., 2006)*. For partial lard replacement, the authors used pre-emulsified linseed oil (8 parts water, 1 part soy isolate, 10 parts linseed oil). Due to the higher proportion of PFA in linseed oil, an antioxidant (butylated hydroxytoluene and butylhydroxyanisole, both at 100 mg/kg) was applied to the salami as well. The salami was packaged (modified atmosphere or vacuum) after 10 days of fermentation and maturation, and samples for analysis were collected after 2 and 5 months of storage. Due to the addition of antioxidants, there were no statistically significant differences in TBARS between the control sample (75% lean pork and 25% lard) and the test samples (25% lard replacement with pre-emulsified linseed oil). The form of packaging played no role either.

After 2 months, the n-6/n-3 FA ratio was > 13 in the control samples while in the tested batches the range was 2.2-2.7 *(Valencia et al., 2006)*. This was due to the higher proportion of the n-3 FA (ALA) in linseed oil.

According to *Muguerza et al. (2001)*, up to 25% of lard in fermented salami can be replaced with olive oil without negative technological or sensory variations in the final products. The study prepared pre-emulsified olive oil (8 parts hot water, 1 part soy isolate and 10 parts olive oil) and this was used as a partial replacement for dorsal lard (10, 15, 20, 25 or 30%) in the traditional Spanish Chorizo de Pamplona salami. The proportion of fat in the final products was 33.9% (control), while in the reformulated samples it ranged from 31.3% to 32.5%, with no significant differences. However, with a fat substitute of 30%, dripping fat from products was recorded during maturation, which is not desirable. No rancid taste was noticed in the final products, nor was the hexanal content different from the control in the reformulated samples. However, the control sample showed the highest stiffness and gummy values ($p < 0.05$).

Application of encapsulated oil

Microencapsulation is an effective technique for increasing the oxidative stability and preventing the thermal degradation of FA in FA-rich n-3 oils *(Heck et al., 2017)*. Microencapsulation refers to a process in which tiny droplets of base material are coated with a microencapsulating agent such as alginate or whey protein. Spray drying has proven to be an effective technique for protecting vitamins, minerals and flavouring additives. In the case of fish oil, microencapsulation also serves to suppress residual fish aroma and flavour *(Keenan et al., 2015)*.

Microencapsulation of oils facilitates their application in foods, delaying their oxidation, masking unwanted aroma or flavour in the final products and also improving the availability of n-3 FA *(Jiménez-Colmenero, 2007)*.

Keenan et al. (2015) prepared a total of 40 servings of beef burgers with a fat content of 40%. In selected samples, the fat was partially replaced (up to a fat content of 15%, i.e. up to 6% of the total burger composition) with two

commercial fish-oil products, one of which was encapsulated and the other unencapsulated. Vitamin E was added to some samples in a proportion of up to 0.015%. The analyses were done immediately after the burgers were prepared and during their storage (4 °C, packed in a protective atmosphere) for up to 15 days.

The partial replacement of fat with fish oil increased the n-3 FA proportion in the burgers, although SFA and MFA dominated due to the high proportion of natural fat. Interesting results were obtained from the TBARS analysis. The burgers with encapsulated fish oil showed a higher degree of oxidation than their non-encapsulated fish-oil counterparts or natural fat-based burgers. Yet encapsulation was expected to protect the fish oil from oxidation. However, literature has already produced results consistent with the findings of the authors of this study. One explanation may be the oxidation of the fat already during the emulsification process prior to drying, while the drying itself may have caused oxidation due to the higher temperature and sensitivity of PFA to heat, and finally the large surface of small droplets of micro-encapsulated fish oil may increase the susceptibility of the fat to oxidation *(Keenan et al., 2015)*.

Losses during heat treatment (grilling after reaching an internal temperature of 72 °C, turning every 3 min) were highest for non-encapsulated fish-fat burgers, lowest for encapsulated-fat products. Samples containing only natural fat were more cohesive than their fish-oil counterparts. Burgers with the highest degree of natural fat substitution with fish oil were also the least stiff. The results confirmed that the composition and properties of fat strongly affect texture, especially in the case of meat products.

Sensory evaluation showed greater acceptance of the control samples by the evaluators compared to the burgers with partial fat replacement. In addition, some evaluators commented on a fishy or unnatural aroma and flavour with the fish-oil samples.

Heck et al. (2017) also tested the possibility of the partial replacement of lard in burgers. The microencapsulation method was used to treat chia oil and linseed oil together with a 2.0% sodium alginate solution and 0.1M calcium chloride. The microparticles contained more than 86% oil. Samples of burgers were prepared (5 kg per sample) containing beef (78.4%), lard (20.0%), salt (1.5%) and garlic (0.1%) - control, the test samples had 50% lard replaced with microparticles containing chia oil or linseed oil. The burgers were cooked on an electric grill preheated to 150 °C to reach an internal temperature of 72 °C *(Heck et al., 2017)*.

Compared to the control (13.4%), the test samples showed a lower fat content ($p < 0.05$) with 10.0% chia oil microparticles, 11.3% microencapsulated linseed oil. There were no statistically significant differences in the colour parameters *a** and *b** between the control and the two test samples (p > 0.05), however a higher lightness value *L** was measured in the lard-oil samples (p<0.001). These samples also showed higher cohesion values (p<0.05) compared to the control. Fat reformulation reduced the proportion of SFA and MFA while increasing PFA (p<0.001). On the other hand, fat reformulation resulted in increased lipid oxidation (increased TBARS values), especially after the heat treatment of the burgers (p<0.05). The samples including linseed-oil microparticles were sensorially acceptable for the evaluator *(Heck et al., 2017)*.

Application of oleogels (organogels)

The simple replacement of animal fats in meat products with vegetable oils is used very little today. This is mainly due to the influence on the texture and sensory properties of the final reformulated products *(Gravelle et al., 2012)*. Preference is given to so-called structured oils *(Barbut et al., 2016a)*. Structuring edible oils through the addition of gelling agents has great potential for use in the food sector. The organogels (oleogels) thus produced have already found applications in both the pharmaceutical and the food industry.

Oleogel (= organogel) is defined as an organic fluid trapped in a thermo-reversible three-dimensional gel network. Either polymers or low molecular weight organic gelling agents (LMOG from low-molecular-weight organogelators) are used as gelling agents for organogels. Polymers have the greatest potential in the food and pharmacy sector thanks to their chemical purity and lower cost *(Stortz et al., 2012)*. This group includes, for example, ethylcellulose (E 462). Its use in the preparation of oleogels requires heating up to 140 °C, which is the value of the glass-transition temperature for this substance. In the case of oils, the issue is the conversion of liquid fats into gel-form materials without altering their chemical properties *(Patel, Dewettinck, 2016)*.

Barbut et al. (2016) tested an organogel from canola oil and ethylcellulose in ground-meat products. Individual batches using beef and tallow, or fat replacements, were prepared. The formulation was designed to contain 11% protein and 26% fat. The lean beef had a fat content of 7.8%, so the remaining 18.2% was beef tallow (fat content 76.6%), or liquid canola oil, or organogel containing ethylcellulose and canola oil as solvent. The authors used canola oil as it contains a lower SFA proportion than other vegetable oils.

The product was filled into cellulosic casings with a diameter of 32 mm, while the individual portions of 16 cm (110 g) were obtained by hand twisting. The product was heated to achieve an internal temperature of 72 °C. The organogels used were prepared with a proportion of ethylcellulose (hereinafter “EC”) at 8, 10, 12 and 14%. Organogels containing a surfactant, namely sorbitan monostearate (hereinafter “SMS”; E 491), namely 1.5% or 3.0% of SMS, were also used in the experiment.

The use of canola oil as a substitute for beef tallow in finely ground meat products provided increased stiffness. The reason was small droplets of vegetable oil dispersed in the product. These small particles mean that a larger surface area of the protein membrane is formed around them (called interfacial protein film). Increasing the surface area of the protein membrane simultaneously increases the resistance of the product to compression, thereby increasing its rigidity. The organogel used in the tests had the ability to reverse this condition, and samples with an organogel fraction (10% EC) showed the same stiffness as the control with the bovine fat. Thus, structured liquid vegetable oils in the form of organogels can be used to replace animal fats in meat products without adversely affecting the texture of the final products.

Batches containing organogels showed lower heat-treatment losses or higher yield. In contrast to the control samples, however, samples with the organogel fraction, or canola oil, had higher lightness values *L** and lower red values *a**. In the sensory evaluation, some evaluators detected a chemical flavour in the samples, probably from the EC. Some also complained about a rancid flavour caused by the high PFA proportion. When preparing the organogel, temperatures of 140 °C were reached, leading to increased oxidative rancidity. This problem was later remedied by applying an antioxidant to the oil before heating it.

The sausages with added organogel prepared with 8 or 10% EC and 1.5% SMS showed stiffness which was not statistically significantly different from the control samples made from beef and tallow, but significantly lower than found in canole oil sausages. The addition of SMS affected the texture and plasticity of the organogel – the structure was stiffer. In the SMS-containing organogel samples, two thirds of the evaluators again detected a chemical flavour. This was later masked by the addition of rosemary oleoresin *(Barbut et al., 2016a)*.

The same team of authors evaluated the use of organogel in the preparation of coarsely ground pork products, namely the breakfast sausage *(Barbut et al., 2016b)*. The breakfast sausage (BS) was made from pork leg (protein content 19.9%, fat content 8.6%), pork flank (protein content 10.9%, fat content 36.9%) and back fat (fat content 86.9%, protein content 3.3%). Individual BS samples of 2.2 kg were formulated to contain 14.3% protein and 20.8% fat. The BS recipe had a proportion of 70% lean meat, which contributed 6.4% fat to the sample. Lard, canola oil, or canola oil organogel was provided to make up the remaining 14.4%. The product was filled into collagen casings with a diameter of 23 mm, the individual portions were 10 cm in length and were immediately cooled to 5 °C *(Barbut et al., 2016b)*.

The analysis of the texture profile of the BS samples showed that the use of canola oil in liquid form or as an organogel resulted in a decrease in the stiffness of the prepared products compared to BS with pork lard. The differences were statistically significant. However, these results were different from those in the previous test for finely ground beef products *(Barbut et al., 2016a)*. This is most likely due to the size of the fat particles (beads) in the coarsely milled BS (>100 μm) that were much larger than the fat particles in the finely ground sausages (10 μm diameter). The sensory assessment also provided the same results in the BS stiffness assessment. However, the subsequent application of the SMS surfactant (1.5%) in combination with 10%, 12% or 14% EC caused greater stiffness in the BS samples, up to that of the lard sample level. This is because the addition of SMS increased the stiffness of the organogels *(Barbut et al., 2016b)*. However, in the sensory assessment, the batches with organogels were again judged to be softer compared to the control.

The application of organogels led to a decrease in the lightness value *L** compared to the BS samples with lard or liquid canola oil. The differences were statistically significant. The vegetable-fat batches were less juicy than those with lard. As butyl hydroxytoluene (BHT) and rosemary oleoresin were added to the oil as antioxidants before it was converted into organogel, the evaluators did not detect "rancid" or "chemical" tastes in the sensory analysis.

Kouzounis et al. (2017) used other gelling agents, particularly monoglycerides and phytosterols, to make sausage oleogels. The oleogel was based on sunflower oil. In addition to the preparation based on monoglycerides (min. 95%), a mixture of the vegetable sterols Vegapure 867G (*β*-sitosterol 60-80%, *β*-sitostanol 0-15%, campestanol 0-5%, campesterol 0-15%, brassicasterol 0-15% and others 0-3%) was applied. The oleogel was prepared with 20% added gelling agent in a 3:1 monoglyceride/plant sterol ratio. The reason for this combination was that when phytosterols are present in small amounts with monoglycerides, they interact with them to form a crystalline network capable of immobilizing sunflower oil. The mixture was heated to 90 °C for 60 minutes then cooled to 18-20 °C.

Two sausage recipes were prepared, one containing only lard (200 g/kg), the other with 50% lard replaced with organogel. The product was filled into collagen casings and heated to provide a core temperature of 72 °C. The lard-containing sausages (with no addition of vegetable fat) showed higher stiffness, brittleness, gumminess and chewability compared to the samples with half the lard replaced with oleogel ($p<0.05$). Coherence and flexibility did not differ between the samples ($p>0.05$). An instrumental surface colour analysis showed a higher lightness value L^* ($p<0.05$) for the samples with the oleogel content, but a lower red colour a^* ($p<0.05$) for the same samples. The same differences in both values were found in sample sections ($p<0.05$), meaning that the sausages with the partial replacement of lard with oleogel were paler than the standard sausages. TBARS test results did not reveal statistically significant differences between the two sample groups. Although the vegetable-fat sausages had a higher unsaturated FA content, the applied dosage form (i.e. oleogel) did not increase lipid oxidation even during storage for 40 days at 4 °C (vacuum pack). The sensory analysis revealed no statistically significant differences in appearance, chewing feel in the mouth, taste or overall sample acceptance ($p>0.05$). However, the standard sausages were better evaluated for colour and aroma, while the sausages with vegetable oil were perceived as juicier by the evaluators *(Kouzounis et al., 2017)*.

Hydrogels represent something of a transitional form of application. In this case, a stable oil-in-water emulsion is transformed into a hydrogel with high water content and low fat content. The analogues thus prepared can be used to prepare low-fat products. *Alejandre et al. (2017)* produced a hydrogel with 3% kappa-carrageenan and 1% seaweed oil (*Cryptheco-dinium cohnii*), while the water content of the freshly prepared hydrogel was 95.86%. This analogue was applied to beef burgers, the basic ingredients of which were lean beef meat and pork fat (in Table 5 designated as control/R). The control samples had a fat content of 9%, while the pork fat was replaced by hydrogel in the samples tested (in Table 5 designated as test/R). The prepared burgers (9 cm diameter, 1.5 cm height) were analysed raw and after heat treatment (180 °C/8 min. hot-air oven; designated as control/T and test/T). The results are summarized in **Table 5**.

As may be seen in **Table 5**, the application of hydrogel was able to reduce the fat proportion in both raw and cooked burgers to below 3%, which allows the use of the term "low-fat". Compared to control, standard samples, the fat proportion was reduced by 70%. The favourable n-6/n-3 FA ratio should be highlighted with the modified samples tested. In the sensory analysis, the tested batches with hydrogel were evaluated as acceptable *(Alejandre et al., 2017)*.

Hydrogel with a linseed oil content of 40%, 58.5% water and 1.5% carrageenan was tested as a partial dorsal lard substitution in long-life fermented salami by *Alejandra et al. (2016)*. Polysorbate 80 was applied to the oil as a surfactant at a concentration of 0.12 g/100 g of emulsion. The gel was chilled to 4 °C after preparation and processed into the product the next day.

Table 5: Composition and TBARS values in standard and low-fat burgers
(source: Alejandre et al., 2017)

	Control/R	Control/T	Test/R	Test/T	SEM	hodnota *P*
Water (%)	68.6[b]	63.6[a]	77.1[d]	71.7[c]	1.0	0.001
Fat (%)	9.0[b]	8.8[b]	2.6a	2.7[a]	0.7	0.001
Protein (%)	22.4[b]	26.4[c]	18.6[a]	23.0[b]	0.6	0.001
Energy (kJ/100 g)	712[d]	647[c]	343[a]	404[b]	51	0.001
Fat reduction (%)	-	-	70	70	2	
Energy redukction (%)	-	-	43[a]	37[a]	3	
EPA	3.4[b]	4.1[b]	2.7[a]	2.7[a]	0.2	0.04
DHA	10.5[a]	11.6[a]	21.7[b]	24.3[b]	2.6	0.001
EPA+DHA	13.5[a]	14.9[a]	24.4[b]	26.9[b]	2.4	0.04
n-3 FA	68.9[b]	72.6[b]	37.5[a]	34.6[a]	7.7	0.003
n-6 FA	1 108[b]	1 091[b]	268[a]	264[a]	144	0.001
n-6/n-3	16.1[b]	15.0[b]	7.1[a]	7.6[a]	1.1	0.001
Polyunsaturated FA	1 116[b]	1 239[b]	357[a]	303[a]	147	0.001
Saturated FA	3 665[b]	3 530[b]	1 146[a]	1 102[a]	477	0.001
TBARS	0.87[b]	0.83[b]	0.52[a]	0.59[a]	0.03	0.001

Note: Control/R: beef burgers with lean beef meat and pork fat; Control/T: beef burgers with lean beef and pork fat after heat-tretment 180 °C/8 min in hot-air oven; Test/R: beef burgers with lean beef meat and hydrogel; Test/T: beef burgers with lean beef meat and hydrogel after heat-tretment 180 °C/8 min in hot-air oven;SEM = standard error of diameter; different indices for individual parameters within 1 row (a, b) indicate statistically significant differences (p<0.05); FA values in mg/100 g of product; TBARS values in mg of malondialdehyde/100 g fat.

Four batches were prepared (6 kg each) with a control of 75% lean pork and 25% loin lard, followed by 3 test samples in which the lard was partially (26.3%, 32.8% and 39.5%) replaced with the prepared linseed-oil hydrogel. Replacing a portion of the fat affected the chemical composition of the final products after maturing. There was no difference in the water content of the control (29.3% of water) and the sample with the 26.3% lard replacement, but the other samples showed a higher proportion of water (30.9% and 32.0%) and this difference in water content was statistically significant (p<0.05) between both the first samples and the higher lard-replacement samples and between the latter samples (32.8% and 39.5% respectively). The use of hydrogel caused a reduction in the fat proportion in the fermented salami. The control sample contained 30.8 grams of fat in 100 grams of product; the fat content was reduced by 6, 14 or 18% in the reformulated samples. This was a reduction in the energy value of 4, 8 or 10% *(Alejandre et al., 2016)*.

In the linseed oil used to prepare the hydrogel, 58.9% ALA of the total FA was found. As a result, the n-6/n-3 FA proportion changed in the final salami from 10.2 (control sample) to 2.5, 1.9 or 1.6 in the reformulated samples based on the percentage of lard being replaced. Increasing the PFA content did not lead to higher lipid oxidation. TBARS values differed only statistically insignificantly at the end of maturation ($p>0.05$). However, the aldehydes content was also analysed in the study. Differences were recorded in the hexanal content but were not statistically significant ($p>0.05$). However, the nonanal concentration was higher for the samples with a higher lard-replacement percentage ($p<0.05$), with the 39.5% lard substitute sample showing the highest nonanal content, this fact also likely being the reason for a significantly strong strange flavour at this sample. This sample was assessed as unacceptable in terms of flavour and taste in the sensory examination. Conversely, a 32.8% lard sample was sensorially acceptable *(Alejandre et al., 2016)*.

Fat as part of vegetable ingredients

A number of plant-derived raw materials were tested as ingredients in meat products. The fat component plays a key role in some of them. Walnuts are one example *(Jiménez-Colmenero, 2007)*. Walnuts have a fat content of 62-68% and are a rich source of oleic acid (18% of total FA), but especially PFA (linoleic acid 58%, ALA 12%), E vitamins, and polyphenols of additives with positive effects on the human body.

Ayo et al. (2007) prepared three batches of sausages whose composition is shown in **Table 6**.

Table 6: Recipe for sausages (%) using walnuts to replace lard
(source: Ayo et al., 2007)

Sample	Pork	Back fat	Nuts	Water	Caseinate	Salt	Phosphate	Nitrite
NF	58	20	0	19.3	0	2.5	0.18	0.015
LF	58	4	0	33.3	2	2.5	0.18	0.015
WF	58	0	25	14.3	0	2.5	0.18	0.015

NF = standard, LF = low-fat sausages, WF = sausages with 25% added walnuts

The product was filled into cellophane casings with a diameter of 20 mm and heated until an internal temperature of 70 °C was reached.

Laboratory analysis revealed that the LF sample with low fat content (6.90%) contained the highest proportion of water (75.03%). The sample with the nuts had the highest fat content (18.51%) while having the lowest water content (55.77%). The protein fraction varied from 13.40% (NF) to 16.59% (WF). This sample also had the highest minerals proportion (3.14%).

While the SFA content was practically the same in the NF and LF samples (38.59% and 38.65% respectively), the WF sample showed a statistically significantly lower proportion (11.89%). Similarly, the MFA proportion (18.15%) was significantly lower in this sample, while the MFA proportion of total FA exceeded 46% in the remaining two samples. On the other hand, the PFA proportion in the WF sample reached almost 70% of total FA, while in the NF and LF samples it was 13.61% and 15.32%. The n-6 to n-3 FA ratio was also favourable in the WF sample (4.89) while in the NF sample it reached 13.73 and in the LF sample 15.63.

The reformulation of meat products or oven-ready meat preparations involves not only reducing sodium (salt) but also the issue of the fat component. The intention may be to reduce the fat level in the final product and thus the total energy value or to partially substitute lard or beef tallow lipids with a higher proportion of unsaturated fatty acids.

While a few years ago the reformulation of fat in a product was carried out by simply adding vegetable oil and/or fish oil, later it was followed by pre-emulsified or microencapsulated fat. In recent years, researchers have been focusing on the use of a fat source replacement in the form of so-called oleogels. The modification of the application form of the fat substitute usually limits the oxidation of the sensitive PFA in the final products. There are also only minimal variations in the texture of the reformulated products compared to standard products. However, attention should always be paid to the colour and taste of the processed products. In many cases, evaluators detect differences that reduce the attractiveness of reformulated products to consumers.

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Innovation of recipes in the confectionery industry

Čopíková J.

Confectionery, cocoa powder and sweetened cocoa powder, chocolate and chocolate products are foods that must meet the requirements of Act No 110/1997, on food and tobacco products and on amendments to certain related acts, as amended. Chocolate is the first food product that was defined by the first directive on food in the European Economic Community in 1973, while the Czechoslovak standard was at that time fully compliant with this Directive. The latest legislative changes concerning confectionery and chocolate are set out in Decree No 76/2003, laying down requirements for natural sweeteners, honey, confectionery, cocoa powder and sweetened cocoa powder, chocolate and chocolate pralines, as amended by Decree No 43/2005. The tables for this decree describe the breakdown of products into groups and subgroups, and their physical and chemical properties. Given that chocolate, in particular, and confectionery to a lesser extent, is clearly defined by legislation, it is necessary to consider whether recipe changes will still comply with the legislative requirements for the composition of chocolates and confectionery **(Table 7)** *(Čopíková, 1999)*.

Changes in the offer and recipes of chocolate and confectionery products have both commercial reasons (producers' efforts to come up with new products) and are also intended to increase the intake of important ingredients such as vitamins, fibre and milk proteins in popular foods. Last but not least, the direction of the expansion of the offer of chocolate and confectionery products is manifested in such a way that these products are acceptable for consumers with certain dietary restrictions. There are also attempts to return to local recipes, while consumers may be interested in confectionery with oriental or unusual ingredients. So, in summary, if chocolate and confectionery products with new recipes are examined or produced, these foods offer the following benefits:

1. Chocolate and confectionary products have increased content of vitamins, antioxidants and minerals. Confectionary such as candy, caramel, and jelly best fulfil this requirement.
2. Chocolate and confectionary products have reduced energy values, meaning they contain less sugar and fat. This requirement may most likely be met by jelly.
3. Chocolate and confectionary products intended for a particular diet. This means a substitution of sucrose with sugar alcohols (polyols) or additives such as natural stevio-

side-like substances. This group also includes products with no lactose or gluten.

4. It is also worth mentioning products with increased energy value, meaning products intended for people requiring increased energy intake, and this may be chocolate with a traditional recipe.
5. There are also new food formulas as well as chocolate and confectionery which are a response to the popularity of exotic flavours and fragrances or local traditional practices *(Jeffery, 2004)*.

Table 7: Chocolate composition [%] - Annex No 9 to Decree No 76/2003

	Cocoa butter (%)	Total dry non-fat cocoa solids (%)	Total dry cocoa solids (%)	Milk fat (%)	Total fat (%)	Milk or milk material (%)	Flour or starch (%)
Chocolate	18	14	35	-	-	-	-
Milk chocolate	-	2.5	25	3.5	25	14	-
White chocolate	20	-	-	3.5	-	14	-
Chocolate a la taza	18	14	35	-	-	-	max 8
Chocolate familiar a la taza	18	12	30	-	-	-	max 18

When designing a new recipe, it is necessary to consider the technological conditions of the chocolate or confectionery production. In summary, chocolate production takes place at temperatures of up to 80 °C, so theoretically it is possible to add nutritionally beneficial substances, but legislation makes it difficult to change the composition of chocolate. There are many more possibilities for the production of confectionery bars with some chocolate content. When producing confectionery like fudge and toffee, account must be taken of the temperature range of 100 °C to 160 °C, which excludes the addition of substances that decompose at higher temperatures. In the case of jelly, the situation is much more favourable because the technological temperatures are lower than with candy.

Chocolate

Commonly marketed chocolates have an energy value of 2100 kJ/100 g to 2650 kJ/100 g. Chocolate with reduced sucrose and thus higher fat content has higher energy value (2300–2650 kJ/100 g), and these are chocolate labelled as extra bitter, 70% cocoa etc. As this chocolate has a higher total cocoa solids content, it also contains more methylxanthines with a stimulating effect on the human body and polyphenols with antioxidant effects.

Basically, it is difficult to reduce the fat content of chocolate because cocoa butter may be replaced with an equivalent of the same composition at up to 5% of the weight of the chocolate, but it is not possible to replace the fat with, for example, polydextrose. Fat substitution is therefore not possible for legislative reasons, but also for technological reasons. However, if chocolate with reduced fat content in the recipe has been subjected to an electric field in the direction of flow, the spherical particles become elongated in shape and the chocolate has suitable rheological properties *(Tao, 2016)*.

Milk chocolate may contain a 14-25% milk component, depending on the use of milk powder with 25-26% milk protein or skim milk with 35-36% protein. Up to about 2% whey powder may be used in a milk chocolate recipe, resulting in increased milk proteins content.

Chocolates suitable for certain diets contain polyols such as glucitol, lactitol and maltitol. The polyols generally have lower sweetness and the formulations may then contain an acesulfame sweetener.

Chocolate contains about 1% emulsifier, either lecithin alone or a combination of lecithin with a polyglycerol polyricinoleate-type emulsifier. Thanks to the emulsifier, it is possible to reduce the fat content of chocolate and also reduce fat bloom on the surface of the product. Recently, there has been demand for a polyglycerol polyricinoleate-free chocolate, and sometimes for no emulsifiers at all. Only soy lecithin was used, which is also unacceptable for some consumers, so egg lecithin is also used.

In any case, chocolate itself is a rich source of energy with a balanced taste, making it a good food for people needing increased energy intake such as athletes, people working hard and soldiers in combat.

In the case of filled chocolates and other chocolate confectionery, dried fruit or nuts containing omega fatty acids can be used in the product.

Recent changes in chocolate and filled chocolate confectionery include exotic spices, healing herbs, hops extracts, dried hemp, dried Pleurotus sp. mushrooms and even dried crickets. Yet it is necessary to consider whether this is still chocolate.

Chocolate and cereal bars

Bars are actually of two kinds: various fillings enrobing with chocolate or cereal bars which can also be enrobing with chocolate. This type of confectionery offers a plethora of ways to formulate and innovate recipes. Nutritionally balanced bars should have an energy ratio of 40:30:30 composed of carbohydrates, fat and protein. Polyols, fats with the desired fatty-acid composition and milk proteins, soy, whipped egg white and gelatine may be found in the bar recipe as proteins. Bars also include cereal fibre, dried fruits, nuts and various seeds such as sesame. The bars can be enriched with vitamins and thus be a source of vitamin A, vitamin D, zinc and calcium. Chocolate and cereal bars are useful for fast satiety during the day and can therefore be a suitable source of proteins, vitamins and other nutritionally important substances, depending on their composition.

Candies and caramels

Candies are mixes of sugar and glucose syrup and are low in water content (ideally about 1%), mostly acidified, dyed and with different flavours. Currently, almost exclusively natural dyes are used to colour these sweets. For a long time, candy formulas have been enriched with vitamin C (up to 1%), and recommendations are appearing to enrich the current formulations with zinc, which can be added in the form of zinc gluconate, a water-soluble salt. Zinc enrichment should comply with the maximum daily doses for children and adults.

The weight ratio of sugar and glucose or maltose syrup in the formulation depends on the producer and production equipment used, but is usually about 40% glucose syrup and 60% sucrose. Both glucose and maltose syrups and sugar components can be replaced with sugar alcohols, polyols. Glucitol, maltitol and isomalt are used most commonly, and can make up the total mass of the confectionery. Flavouring, dyeing and fortification of polyol confectionery is the same as for classic candies, but polyol sweets are intended primarily for diabetics, have a lower energy value and cause less tooth decay. In particular, filled candies, comprimates and chewing gums may be healthy confectionery if extracts from a range of medicinal herbs are included in the recipe, and this offer continues to be expanded today, e.g. using lavender or echinacea extracts. The filling in the candies can then be a suitable combination of zinc salts and anti-cough extracts (https://ods.od.nih.gov/, downloaded 18. 2. 2019).

Caramels

Fudge and toffee caramels have a formula consisting of sugar, glucose syrup, condensed milk, fat and emulsifier. The enrichment of confectionery with calcium, which is often deficient in the human body, is very problematic, but fudge-type caramels can be successfully enriched with calcium in the form of calcium gluconate.

Jelly

Jelly confectionery contains sucrose, glucose or maltose syrup and a gelling agent. The water content of jelly is around 20%. Since the production temperatures for jelly are lower than for candy, these sweets can be enriched not only with vitamin C and vitamin A (thermally unstable), but also with vitamin D, which rapidly decomposes in an oxidizing environment. Jelly formulas can contain various types of starch, pectin, gellan, agar or gelatine as gelling agent: depending on the composition (pectin or gellan), they need calcium to form the gel. In addition, fruit jellies may be prepared with some fruit juice or may contain dried fruit or fruit pulp *(Richmond, 2015)*.

However, the conclusion of this chapter is that chocolate and confectionery are at the top of the food pyramid for all the inhabitants of our planet *(Lachance, 2005)*, so chocolate is a good source of energy only at times of high energy expenditure. Confectionery with a high content of herbal extracts can be beneficial for colds.

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Reformulating dairy products

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The composition of milk makes it an almost ideal food. It contains all the essential nutrients, minerals and vitamins - but in a composition optimal for young animals **(Table 8)**.

Table 8: Average composition of cow's, goat's and sheep's milk - main ingredients and selected minerals and vitamins per 100g of milk (adjusted according to *Muehlhoff et al., 2013*)

Component	Cow milk	Goat milk	Sheep milk
Energy (kJ)	262	270	420
Water (g)	87.8	87.7	82.1
Proteins (g)	3.3	3.4	5.6
Fat (g)	3.3–4.0	3.9	6.4
Lactose (g)	4.7	4.4	5.1
Ash (g)	0.7	0.8	0.9
Calcium (mg)	112	118	190
Phosphorus (mg)	91	100	144
Potassium (mg)	145	202	148
Sodium (mg)	42	44	39
Zinc (mg)	0.4	0.3	0.6
Iron (mg)	0.1	0.3	0.1
Retinol (μg)	35	45	64
Carotene (μg)	16	traces	traces
Vitamin A (μg RE)	37	48	64
Vitamin E (mg)	0.08	0.05	0.07
Vitamin D (μg)	0.2	0.1	0.2
Riboflavin (mg)	0.2	0.1	0.3
Vitamin B12 (μg)	0.51	0.07	0.66
Vitamin C (mg)	1.0	1.1	4.6

Milk is the base material for a wide range of products, while the possibilities for their reformulation mainly lie in the adjustment of the proportion of the essential nutrients of fat, carbohydrates and proteins, the reduction of salt content and fortification with selected mineral substances or vitamins. In this way, dairy products can be adapted to the needs of different groups of people with specific requirements, e.g. for the elderly and people with lactose intolerance.

Fortification of milk and milk drinks

The reformulation of milk is limited to some extent because, according to Regulation (EU) No 1308/2013 of the European Parliament and of the Council establishing a common organization of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007, it is not possible to take from or add anything to milk except as explicitly stated. These derogations include:

- Adjustment of the milk-fat content (whole milk at least 3.5%, semi-skimmed at least 1.5% and not more than 1.8%, skimmed milk not more than 0.5%). Milk may also have a different fat content, but this must be clearly indicated on the packaging.
- Enrichment of milk by adding milk proteins, mineral salts or vitamins in accordance with Regulation (EU) No 1925/2006 on the addition of vitamins and minerals and of certain other substances to foods (hereinafter "Regulation (EU) No 1925/2006"). Where proteins are added, the protein content of the enriched milk must be at least 3.8% (w/w).
- Reduction of the lactose content by conversion to glucose and galactose.

A varied diet should normally provide sufficient intake of all nutrients. However, lifestyle changes also offer the possibility of reformulating basic foods such as milk. This reformulation may include fortification, which is the process of deliberately increasing the content of essential micronutrients such as vitamins, minerals and trace elements in foods. Foods modified in this way improve their nutritional value and positively affect the consumer's health. For milk, fortification with vitamin D is desirable. The natural content in milk is low and highly variable, depending on the method of dairy farming. The overall intake from food is low in many countries, and vitamin D3 (cholecalciferol) synthesis is also insufficient due to the long periods of time spent inside, air pollution and the use of high-protection-factor sun creams. The daily reference value is 5 µg (Regulation (EU) No 1169/2011). According to the *EFSA panel (2016)*, 15 µg/day is adequate for adults and children over 1 year of age. Milk fortification with vitamin D is common in some states - in Canada it is mandatory for milk and margarine, in the US it is voluntary, but most milk is enriched. Fortified milk has also appeared on the Czech market, and a single 200 ml portion contains 30% of the daily vitamin D dose. More widespread fortification with vitamin D is desirable, especially in the winter due to the lack of UVB radiation. Fortification of condensed- or dried-milk products must not exceed the maximum permitted for products intended for consumption (Regulation (EU) No 1925/2006). If the fortification is performed properly, food hypervitaminosis should not be a risk for consumers - the upper limit is set at 100 µg/day. For fortification, cholecalciferol is usually used in the form of a concentrate in oil or in combination with an emulsifier, where it is water--dispersible. The vitamin is usually added after standardizing the fat prior to heat treatment by batch or continuous dosing pump. The inclusion of homogenization is suitable only after the addition of the vitamin. Vitamin D is stable both when heated and stored *(Yeh et al., 2017)*. Care must be taken during the fortification process to ensure proper dosing (suitable dosing equipment, ensuring homogeneous concentration throughout the volume, avoiding human error).

Other possibilities for fortification - vitamin A, mineral substances (Ca, Mg, Fe, I) - can be considered for milk. Isolated milk components which are subsequently added in concentrated form can also be advantageously used for reformulation. Thus, for example, phosphopeptides obtained from casein may be carriers of mineral substances. Iron enrichment of dairy products is also desirable because of the relatively high incidence of anaemia. According to the WHO *(De Benoist et al., 2008)*, global anaemia prevalence is 24.8%, with developing countries being most affected, but some population groups in Europe are at high risk of iron deficiency anaemia (pre-school children, pregnant women, women of reproductive age in general). Vegetarians are also at risk with regard to the minimal absorption of iron from plant sources. Reduced iron assimilation is also related to higher consumption of milk and milk products due to the interaction of iron with the casein phosphate groups. Concomitant enrichment with vitamin C increases iron assimilation and combinations with prebiotics and probiotics are also suitable. Iron fortification is, however, rather complicated. Some compounds may accelerate lipid oxidation, cause undesirable coloration or have poor sensory properties. Lactoferrin-bound iron has a high utility, but it is a costly method for conventional products. Ferrous lactate and fumarate are also highly available but are not very soluble. In infant formulas, where the content of unsaturated fatty acids susceptible to oxidation is increased, encapsulation or stable iron complex compounds are appropriate. Phospholipid or composite emulsion micelles can be used to encapsulate ferrous compounds.

Dairy beverages and other dairy products also offer a wide range of reformulation options based on the addition of fibre, probiotics and prebiotics or plant sterols. Higher nutritional values could also be achieved by adjusting the fat composition of the product so that it contains a higher proportion of unsaturated and essential fatty acids, but such a product must be properly labelled.

Options for milk fat replacement

The desired reduction in the energy value of a dairy product while maintaining its sensory properties is possible through the use of a milk-fat substitute. There are a number of fat substitutes that can be used in dairy products. Promising directions include the use of microparticulated whey proteins and composite emulsions.

Interest in microparticulated whey proteins was revived after a patent expired *(Singer et al., 1988)*. Microparticulation is based on the thermal denaturation of the whey protein concentrate, which is combined with high shear stresses to form particles similar to fat droplets. The shear stresses prevent the formation of a compact gel. The particle size should be greater than 0.1 μm to contribute to the product texture, while the maximum size should be between 3 and 10 μm as larger particles create a floury or sandy feeling **(Figure 7)**.

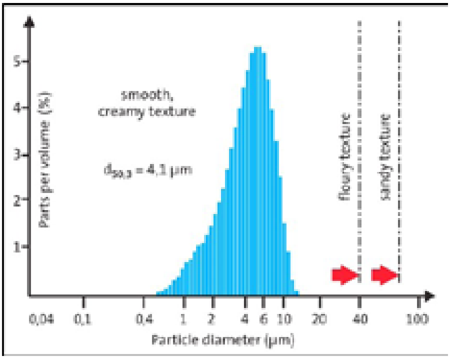

Figure 7: Particle size distribution for microparticulated whey proteins.
(Alpma corporate literature, edited)

Microparticulated whey proteins are also commercially available in dried form. Nowadays, the technology for the production of microparticulate whey proteins is offered by a number of companies. The first technological step is the ultrafiltration of whey, which can be performed to obtain various degrees of protein concentration and the associated lactose/protein ratio. The protein and lactose content significantly affects the course of the microparticulation, and it is necessary to choose the conditions for further processing according to these concentrations. When doing so, it is necessary to achieve the denaturation temperature and at the same time prevent the formation of large particles or gel through shearing. The protein concentration expressed as the percentage of protein in dry concentrate can vary within a wide range of 28-90%. The microparticulation itself is most often carried out after preheating in a scraped surface heat exchanger; another option is to use a conventional heat exchanger in combination with a homogenizer or a combination of a rotor-stator mixer (APV Cavitator) and a scraped surface heat exchanger for cooling. The microparticulation process depends on several parameters. In addition to the above-mentioned protein concentration, these are especially the temperature and the lactose content **(Figure 8)**. A higher denaturing character is required when the lactose content is higher. The temperature of the particles also varies and at higher temperatures the particles are more compact, less deformable, and bind water less.

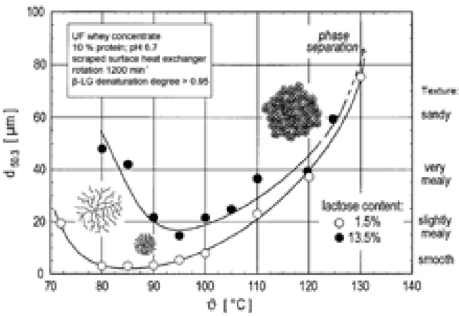

Figure 8: Influence of temperature and lactose concentration on the formation of whey protein aggregates. *(Spiegel, 1999, edited)*

The caloric value of high-fat products can be reduced by tens of percent. Suitable applications include, for example, milk drinks, fermented products, fresh, matured and processed cheeses, curds, desserts, frozen creams, dressings and mayonnaise. For example, *Massoti (2017)* provides an overview of the application of microparticulated proteins in cheeses. When applied to cheese, an additional benefit is an increase in yield.

One interesting way to reduce fat is to use multiple emulsions, where the fat portion of the O/W emulsion can be replaced with an internal W/O emulsion. This can reduce the fat content of whole-milk dairy products (cream, frozen creams, cheeses) by up to 40% while preserving the original sensory properties of the fat droplets *(Jiménez-Colmenero, 2013)*. The W/O/W emulsion may also serve to microencapsulate water-soluble substances sensitive to, for example, the acidic environment of the stomach, or to mask their adverse sensory and technological properties *(Giroux et al., Robitaille et al., 2016)*. The disadvantage of multiple emulsions is their low thermodynamic stability. A combination of a hydrophilic and hydrophobic emulsifiers is required for their preparation. The emulsifying properties of milk proteins can be advantageously utilized as hydrophilic emulsifiers. Polyglycerol polyricinoleate (PGPR, E476) provides the highest stability among hydrophobic emulsifiers *(Jiménez-Colmenero, 2013)*. However, its use is limited by legislation (Regulation (EU) No 1333/2008 on food additives, hereinafter "Regulation (EU) No 1333/2008").

In terms of composition, fat substitutes can also be based on different hydrocolloids. *Rolon et al. (2017)* tested the possibility of fat substitution in ice creams with a fat content of 6-14% with maltodextrin (0–8% dose). The sensory evaluation suggested that the evaluators were unable to distinguish a 2% difference in the fat content between 6 and 12%, a 4% difference was not significant between the 8 and 12% fat samples, however was recorded for samples between 6 and 10% fat.

Hydrolysis of lactose and reduction in sucrose addition in dairy products

The content of carbohydrates in dairy products is given by the content of the milk sugar lactose, while for some products (e.g. flavoured milk drinks, fermented products, frozen creams) their content is increased through the addition of sucrose or other carbohydrates from the flavouring component. The sucrose content of these products is often relatively high, especially in products intended for children, and there is room for gradual reduction. In the case of sweetened condensed milk, the sucrose content cannot be reduced because it ensures the microbial stability of the product.

In recent years, there has been growing interest in products in which lactose has been hydrolysed enzymatically into glucose and galactose monosaccharides. The legislation is not uniform neither in Europe nor in the world. Mostly, low-lactose foods have lactose content of not more than 1 g per 100 g or ml and lactose-free foods contain not more than 10 mg per 100 g or ml. Although these products are primarily intended for people with lactose intolerance, they are often popular with individuals seeking a healthy diet, as in the case of gluten-free foods. Since the lactose hydrolysis products exhibit a sweeter taste, the hydrolysis of lactose in flavoured products can also serve to partially reduce added sucrose without affecting sensory properties. The resulting taste depends on the initial lactose concentration and on other ingredients. Hydrolysis improves the sweet taste of the product because glucose and galactose exhibit 65-80% sucrose sweetness while lactose only 16-20%. For whole milk, an increase in the sweetness equivalent to 0.9% of sucrose can be estimated at a hydrolysis of 90% *(Jelen, Tossavainen, 2003; Wilde, 1998;)*. In addition to increased sweetness and direct absorption, lactose hydrolysis products also have technologically advantageous properties: they are more water-soluble, more fermentable and non-crystallising, but they also exhibit greater reactivity in non-enzymatic browning reactions. The choice of enzyme is important for lactose hydrolysis because multiple commercial preparations with different properties are available. *β*-galactosidase isolated from the yeast *Kluyveromyces lactis* can be used to hydrolyse lactose in milk and other neutral-pH products, the enzyme from *Aspergillus oryzae* with optimum activity in acidic environments (pH 4.0-4.6) for the hydrolysis of lactose in acid whey or in fermented products after fermentation can be used as well. For fermented products, newly available preparations based on enzymes isolated from bifidobacteria which are active over a broader pH range of 4.5-7.0 can be used to advantage.

In the production of lactose-free or lactose-reduced milk, the enzyme can be added before the final heat treatment and subsequently inactivated. Due to the optimal temperature of the enzyme, it is necessary to heat the milk before it is added. This increases the thermal load on the product, the energy costs, while during the second heat treatment, a Maillard reaction between the released monosaccharides and proteins occurs. For high-quality milk, the hydrolysis of lactose can be carried out, for example, after thermization or microfiltration. For hydrolysis, it is advisable to use a lower temperature to reduce the development of undesirable microbiota. The disadvantages are a longer reaction time, which reduces the production capacity, and that a higher enzyme dose sample is required. The use of immobilized enzyme can also be considered, but it is difficult to sanitize an immobilized enzyme device. For UHT milk, the optimal solution seems to be to dispense a small amount of sterile enzyme into a stream of heat-treated milk where the hydrolysis of lactose takes place within a few days when stored at room temperature. In this case, higher purity is required for the enzyme, otherwise undesirable changes in taste may occur during storage.

While the aforementioned sweet taste may not be detrimental to flavoured milk beverages or fermented products - on the contrary it reduces the amount of added sugar - the taste is unnaturally sweet for regular milk. This problem can be solved using patented technology from the company Valio, which consists in the chromatographic separation of lactose from milk, when a part of the lactose is subsequently enzymatically hydrolysed and returned to the milk so that the sweet taste of the milk is preserved. This milk contains 1.4% glucose and 1.4% galactose, while the energy content is 83% of that of untreated milk *(Jelen, Tossavainen, 2003)*. Recently, a new technology based on lactose separation membrane processes has also been mentioned.

The *β*-galactosidase enzyme can also be used under appropriate conditions for the synthesis of galactooligosaccharides, which can serve to reformulate products by replacing the prebiotics used - usually based on fructooligosaccharides. The advantage is the use of ingredients of dairy origin.

Reducing salt content in dairy products

The issue of salt reduction is very topical in the Czech Republic, as salt intake here is about three times higher than the WHO recommendation (less than 5 g NaCl/day). A high salt intake is associated with hypertension, coronary artery disease and stroke. This reduction in salt content mainly affects natural and processed cheeses. With the exception of quarg, salting (depending on the type of cheese - immersed in brine, applying crystalline salt to the surface of the cheese or blending into the curd) is one of the basic and essential steps of traditional natural cheese technology. As may be seen in **Table 9**, the salt content is very variable in cheese depending on the type of cheese. While it is usually low, sometimes negligible in fresh cheeses and curd, maturing soft cheeses contain more than 2.5% NaCl and some up to 5%. The highest content is in white cheeses (Balkan, Akawi, Jadel) due to their preservation and storage in brine, which is characteristic for them.

The significant reduction in salt content in natural cheeses is limited by the fact that, in addition to the sensory function, salt affects the activity of native and microbial enzymes, rennet and cultures and is significantly involved in the formation of texture. Reducing water activity has a significant impact on the growth and activity of both starter and non-starter cultures, thus significantly affecting the maturation of cheeses and having a preservative effect. From this it is clear that a strategy of the gradual reduction of the salt content in cheeses has considerable limitations. NaCl replacement with potassium chloride is most commonly used, and although potassium ions have a bitter, chemical or metallic taste, a 50% substitution is acceptable. The taste of KCl can be partially masked with sodium glutamate, amino acids or ammonium chloride *(Silva et al., 2013)*.

In processed cheeses, the sodium content is not only due to the NaCl content of the original natural cheeses, but also to added melting salts such as sodium phosphates or citrate. The declared NaCl content is thus usually increased by 1.5-2%. As with natural cheese, here it is possible to reduce the sodium content by partially replacing it with potassium salts. *Hoffman et al. (2012)* verified the suitability of a number of combinations of amounts and proportions of potassium and sodium salts of phosphates and citrates in the production of block-type processed cheeses. The formula with the lowest sodium content that still had appropriate sensory properties in terms of both taste and texture had a 0.16% reduction in Na (i.e. approximately 30% of its original value) and an increase in potassium content of 0.25% (i.e. approx. 50% of the original value). *Shatz et al., (2014)* even achieved a reduction in sodium content of up to 60% compared to a non-potassium salt formulation. The limitation in replacing sodium salts is the insolubility of potassium polyphosphates – yet the use of polyphosphates in melting salt mixtures is essential for their proper functioning and for achieving the desired texture.

A second way to reduce the sodium content is to reduce the dose of melting salts, which is also desirable in terms of phosphate content. However, this may result in a deterioration in the texture and stability of the product. Possibilities for achieving a significant reduction in the content of melting salts by using other additives have similar functional properties, emulsifying ability, calcium binding, water binding and protein matrix structure are being investigated. For example, these are some emulsifiers *(Cell et al., 2007; Lee et al., 1996)* and anionic hydrocolides such as pectin *(Liu et al., 2008; Macků et al., 2008)* or starches *(Ye et al., 2009; Trivedy et al., 2008)*. However, it has so far been possible to achieve only a partial reduction in the amount of melting salts, since the sensory properties of such products differ from processed cheeses and, moreover, at higher starch doses (which can be understood as substitutes for milk proteins) they are classified as imitations or analogues of cheese.

It should be noted, however, that the reformulation of cheeses in terms of salt content may not have a major impact on high sodium intake because at the current average consumption of 13 kg of cheese per person per year with an average content of 2% NaCl, cheeses account for only about 5% of total salt intake. However, these are average values and the situation may vary from person to person depending on their preference for cheese types.

Table 9: Sodium and NaCl content in different types of cheeses *(Drbohlav, Vodičková, 2001)*

Product	Dry matter (%)	Fat (%)	Na (mg/100g)	NaCl (%)
Quarg low fat	25.0	2.0	29	0.1
Quarg hard	32.0	0.9	30	0.1
Fresh cheese	42.7	26.5	325	0.8
Gervais	30.9	15.0	34	0.1
High fat fresh cheese spread	45.5	33.5	171	0.4
Balkan cheese	41.5	20.5	1 764	4.5
Akawi	47.0	19.7	2 638	6.7
Jadel	57.9	22.5	2 296	5.8
Hermelín – camembert type cheese	49.4	22.2	1 112	2.8
Niva	55.1	28.9	1 833	4.7
Romadur	47.7	19.9	1 063	2.7
Olomoucke tvaruzky	38.1	0.9	1 918	4.9
Tilsiter	50.5	12.8	414	1.1
Zlato – Bel Paese type cheese	53.8	27.5	840	2.1
Cheddar 45 % tvs	58.8	26.3	488	1.2
Edam 30 % tvs	51.6	16.0	849	2.2
Edam 50 % tvs	59.2	30.2	690	1.8
Caciocavallo cheese	56.9	26.0	1 015	2.6
Maasdamer cheese	58.3	26.5	632	1.6
Emmental	62.3	26.6	229	0.6
Processed cheese – low fat, spreadable	31.2–38.5	6.4–11.5	924–1 347	2.3–3.4
Processed cheese – high fat, spreadable	45.0–52.4	27.5–39.0	850–1 060	2.2–2.7
Processed cheese – cuttable	49.4	23.5	1 116	2.8

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Food reformulation - fat products

Filip V.

The current knowledge of the effect of trans fatty acids (TFA) on human health, where the influence of fatty acids on blood serum lipoproteins is mainly observed, necessitates their substitution. Since the main source of TFA in nutrition is partially hardened fats, this means the need to replace the process of partial hardening of vegetable oils with other technologies or other available vegetable fats, especially palm oil. Where the character of traditional spreadable fats, as fats and blends and shortenings is to be maintained, reformulation is starting to replace TFA with saturated fatty acids, a component with lower risk to human health.

The reformulation of fat foods and products in terms of nutrient changes and the reduction in the content of some substances in the oil and fats segment focuses mainly on vegetable oils and fats and their products. The main constituent affected previously and currently by the changes are unsaturated fatty acids with the double bond configuration in the trans position, the reduction of saturated fatty acids and optimization of the essential fatty acid content. From the perspective of fatty acid representation in triacylglycerols, the issue of reducing the energy value of foods containing fat is secondary.

The following may be considered for reformulation:

- refined vegetable oils (liquid) and products based thereon, including deep-frying and frying oils;
- spreadable fats and shortenings that can be physically characterized as “fats of suitable consistency”;
- fats for other applications such as coating and filling fats, fats for ice cream and others; this group may partially overlap with the previous one. From the physical point of view - in terms of consistency/texture - the requirements placed on them, as on “fats of suitable consistency” are more specific and more demanding than in the previous group.

The decisive source for the formulation of fat products are vegetable oils and fats (global production in 2019 > 208 million tonnes), while the global production of animal fats such as lard, tallow and fish oils is stagnating, with the exception of milk fat (approx. 26 million tonnes in 2017; source: https://www.indexmundi.com/agriculture/). A fundamental problem that arose in the 19th century and became fully apparent during the last century was the disproportionate need for “fat of suitable consistency” for fat products. Ways were therefore sought to modify the available vegetable oil raw materials to obtain fats of the desired physical properties. In the last century, this problem was solved globally through the process of partial catalytic hydrogenation of vegetable oils, whose main product was trans unsaturated fatty acid isomers, particularly partially hardened fats such as soybean, sunflower, rapeseed and cottonseed. These usually contained > 50-60% of trans unsaturated fatty acid isomers.

Fat consumption and its impact on human health

Scientific findings on this subject are best summarized by the adopted nutritional recommendations (http://www.vyzivaspol.cz/vyzivova-doporuceni-pro-obyvatelstvo-ceske-republiky/). Even though they are updated (the first were published in the former Czechoslovakia in 1986 by the Society for Rational Nutrition), they have been relatively consistent in terms of fat consumption: depending on the nature of the work performed in the adult population, fat should not exceed 30-35% of the daily energy intake, i.e. for those doing non--physical work about 70 g of fat per day. Of this, the saturated fatty acid intake should be less than 10% (about 20 g), and polyenoic FA 7-10%, while maintaining the (n-6) and (n-3) acids ratio at a maximum of 5:1. The trans fatty acid intake should be as low as possible and should not exceed 1% (approximately 2.5 g) of the total daily energy intake. The recommendation also sets a limit on the intake of cholesterol to a maximum of 300 mg per day, including for children. What has changed significantly is precisely the approach to the intake of trans fatty acids (TFA).

The basic and therefore the most widely used model for the effects of fatty acids on human health is their influence on the content of cholesterol-carrying lipoproteins *(Brower et al., 2010; Brower et al., 2013)*: low density lipoproteins (LDL) transport cholesterol from the liver to the periphery, high density lipoproteins (HDL), on the other hand, transport excess cholesterol from the periphery to the liver. High LDL levels are atherogenic, low HDL levels are associated with the development of ischaemic heart disease.

Recent findings and opinions on the effect of fatty acids on serum lipoprotein levels

Without a basic understanding of current knowledge in the field of nutrition, the reformulation of fatty foods cannot be seriously approached.

Short-chain and medium-chain fatty acids (butyric to capric acids, contained in milk fat, coconut and palm kernel oil) at low intake levels act on total and LDL cholesterol and triglyceride levels in a similar way to sugars *(Cater et al.,* *1997)* in respect of which comparative studies are usually conducted.

The group of long-chain saturated fatty acids (C12-C18; lauric, myristic, palmitic and stearic acids): lauric and myristic acids originate from coconut, palm kernel and milk fat, while palmitic and stearic are present in most animal fats, palmitic most in palm oil. These acids generally increase the levels of total and LDL cholesterol and - slightly - HDL cholesterol while lowering the level of triglycerides *(Mensink et al., 2003)*. There are still no unanimous opinions on the influence of stearic acid. It is sometimes said to affect lipoprotein levels like oleic acid *(Mensink et al., 2003)*, but it is also considered in the same way as lauric, myristic and palmitic acids.

The effect of the most important monoenoic oleic acid is usually described in relation to cholesterol levels as neutral, meaning that monoenoic acids have the same effect as carbohydrates in iso-energy diets *(Grundy, 1986; Mensink et al., 2003)*. Older studies of (n-6) polyenoic fatty acids consider them to be hypocholesteromic compared to the effect of dietary sugars, while some recent studies consider them equivalent to oleic acid *(Mensink, Katan, 1992)*, but the latest meta-analyses indicate - when saturated fatty acids are replaced in the diet - a more significant effect of (n-6) acids on the lowering of LDL cholesterol in blood serum than oleic acid under comparable conditions *(Mensink et al., 2003)*. The effect of linolenic acid on the lipoprotein levels profile is reported to be similar to that of linoleic acid.

The influence of trans acids–trans isomers of monoenoic fatty acids, if they replace cis-monoenoic fatty acids (oleic acid): there is an increase in LDL cholesterol and at the same time a decrease in blood-serum HDL cholesterol levels *(Brouwe et al., 2013)*. A similar effect has been demonstrated when substituting a mixture of saturated fatty acids in the diet *(Katan et al., 1993)*. It is therefore the least favourable effect of a single group of fatty acids on blood lipid levels, which has become the main reason for their replacement in fat formulations. A crucial moment for the use of TFA-containing fats was the decision of the American Food and Drug Administration to cancel the GRAS (Generally Recognised As Safe) status for partially hardened fats *(FDA, 2015)*.

Sources of trans fatty acids in nutrition

The most important source of TFA in human nutrition in the 20th century was hardened fats, or more precisely partially hardened vegetable oils. Soybean, sunflower, rapeseed, cottonseed and palm oil were hardened worldwide. The aim of this process was not to obtain saturated fatty acids, mainly stearic acid (this was actually undesirable from the perspective of texture), but a mixture of trans octadecenoic fatty acid isomers bound in triacylglycerols as the main product. Thus, multiple linolenic and linoleic acid linkages and *cis/trans* isomerization of double bonds were saturated. These fats normally contained 50-60% trans isomers, mainly octadecenoic fatty acids, of which only a few percent of dienoic acids. Such a product exhibited optimal physical properties for food applications. Nowadays, if the hydrogenation process is used, it is complete saturation of the double-bonds, so-called full/total hydrogenation. Under these conditions, the main product is stearic acid, while the content of trans isomers is < 1% **(Figure 9)**.

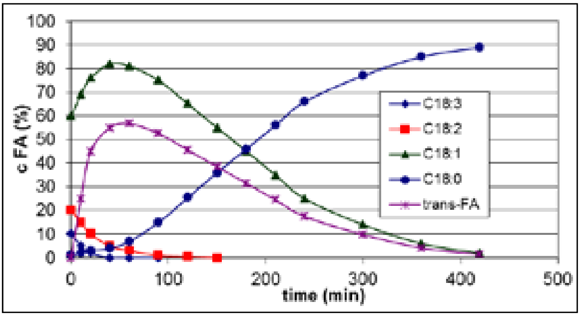

Figure 9: Change in the C18 fatty acid concentration in rapeseed oil during partial hydrogenation (completion of the reaction after about 50 min) and the achievement of complete conversion to obtain fully hardened fat. C18: 3-octadecatrienoic FA, orig. linolenic acid, C18: 2 - octadecadienoic FA, orig. linoleic acid, C18: 1-octadecenoic FA, orig. oleic acid, C18: 0- stearic acid, trans FA-sum of trans isomers of FA (adapted from *Bockisch, 1998 and Svoboda et al., 1997)*

A particular case where partial catalytic hydrogenation technology was used was deep-frying and frying oils produced in the USA. The main requirement was to achieve a substantial increase in the oxidative stability of soybean oil, which was subjected to partial saturation of trienoic FA double bonds (originally linolenic acid) and partially dienoic FA (originally linoleic acid) in order to obtain a product containing monoenoic and dienoic FA. Of course, concurrent *cis/trans* isomerization also resulted in *trans* acids **(Figure 9)** that were also present in the product after fractional crystallization, which was necessary to separate the higher melted triacylglycerols. The resulting product was liquid.

The second basic source of TFA is the milk fat of ruminants, where trans isomers are formed through partial enzymatic hydrogenation and isomerization up to the 3% level (the mean value for the Czech Republic; *Brát et al., 2014)*, with milk fat containing 65% saturated fatty acids. Where the limit of 10% of the total daily energy intake for saturated fatty acids is not exceeded when consuming milk fat, trans isomers originating from milk fat are represented in the order of tenths of a percent, thus there is no risk of exceeding 1% of the total daily energy intake.

The third, even smaller source of trans isomer intake is refined vegetable oils containing up to 1% of trans fatty acid isomers. TFAs in this case are formed by heat induced double--bond isomerization, polyenoic acids are the most reactive *(Kémeny et al., 2001)*. This is a voluntary limit on the producers of refined oil, which can be seen as evidence of good oil refining practice. Anyway, it is a source with a trans acids content 3 times lower than milk fat. Other sources of TFA are already practically insignificant, or they are of secondary origin in the food chain, such as findings in breast milk.

In conclusion, the main potentially significant source of TFA in nutrition remains partially hardened vegetable oils as a raw material for the production of other foods and for meal preparation.

Reformulation of partially hardened oils and fats

It is clear that the partial catalytic hydrogenation technology for modifying the properties of oils and fats cannot be used because one irreversible consequence of it is, in addition to the saturation of the double bonds of fatty acids, their concurrent *cis/trans* isomerization. It is necessary to look for alternative ways for this modification of key importance in the 20th century for the composition and physical properties of triacylglycerol mixtures.

Increased global production of palm and palm kernel oil has significantly affected development (76 million tonnes, or 8.8 million tonnes in 2019), while in 1980 it was only < 5 million tonnes and 0.5 million tonnes (https://www.indexmundi.com/agriculture/). Palm oil has considerable potential, which is further enhanced by its fractionation into 2 base fractions - palmolein with a basic use as liquid oil, and palmstearin as a source of saturated fatty acids *(Kellens et al., 2007)*. Negative aspects include the increased polarity of palm oil and its fractions because, thanks to lipolysis, conventional crude palm oil contains < 5% free fatty acids, which after refining results in a diacylglycerol content of about 10%, while the most serious problems include the increased content of 3-MCPD esters (3-chlorpropandiol, less 2-chloropropandiol) and glycidol esters in refined and bleached palm oil (RBD Palm Oil). This issue cannot be addressed at the current level of technology, given the considerations for introducing limits for these process contaminants.

Frying/deep-frying oils

A key problem for these applications is the high oxidation stability required. For industrial applications, reformulation is usually addressed through the direct use of palm oil or its liquid fraction of palmolein, where higher levels of 3-MCPD and glycidol ester process contaminants are encountered. In addition, 3-MCPD esters accumulate in palmolein, further complicating the situation *(Kyselka et al., 2018)*.

Another possibility is the use of refined olive oil, high oleic sunflower oil, the formulation of blends - e.g. erucic-free rapeseed oil with palmolein - or increasing the oxidative stability of rapeseed (Europe) or soybean oil (US) with synthetic antioxidants, usually TBHQ (tert-butylhydroxychinone) and other additives.

Fats of suitable consistency and their reformulation

Usually, the terms oil and fat are explained with respect to their physical properties: oil is liquid at temperatures above 0 °C while fat appears solid. In fact, the term "fats of suitable consistency", when we mean traditional foods such as butter, lard and tallow in Europe, always means mixtures of mixed triacylglycerols that contain saturated and unsaturated FA in different ratios. Such fats do not show a precise melting point but rather, depending on the tempering temperature, the solid phase melts gradually, which best characterises the dependence of the solids content on the temperature, the SFC (solid fat content) curve.

To understand the problem of reformulation, it is necessary to introduce the concepts of structural fat and fat blend. Structural fat is a constituent of a fat blend that forms a crystalline fraction, a solid phase. The fat blend is made up of structural fat (there may be multiple of these) and the liquid portion of vegetable oils in such a way that the dependence of the solids content on the temperature (SFC curve in the range 5-40 °C) meets the requirements for the given application, or given product type, and crystallization in the desired TAG crystalline modification takes place under the selected temperature conditions. For margarine and mixed fat blends, this is usually a *β´* modification. Such a system can be characterized as an oleogel.

So if we talk about fat reformulation in the sense of the replacement of trans fatty acid isomers with saturated fatty acids, this means a replacement of structural fat based on partially hardened fats in the fat blend with a structural fat that does not contain them. In practice, it is a substitute for saturated fatty acids.

Current replacement options for trans fatty acids in the structural fats of fat blends are:

- suitable mixtures of triacylglycerols obtained by transesterification,
- suitable mixtures of triacylglycerols obtained by fractional crystallization,
- direct use of suitable vegetable fat containing saturated fatty acids.

The direct use of suitable vegetable fats is usually limited to the direct use of palm oil (more correctly palm fat) in fat blends. This possibility is limited by the requirements for SFC curve parameters, while an advantage is the preference for crystallization in the *β´* modification. The possibilities for the direct application of palm oil or palm kernel oil to fat blends are extended through the use of palm oil fractional crystallization products *(Aini, Miskandar, 2007)*.

The main option to replace trans fatty acid isomers of octadecenoic fatty acids with saturated fatty acids is currently the transesterification of a mixture of triacylglycerols. Its essence is to obtain a more suitable distribution of acyls in molecules of mixed triacylglycerols in terms of the requirements for the parameters of structural fats and subsequently fat blends from the point of view of physical parameters such as the dependence of the solid components on temperature (SFC curve), the preference for crystallization in the usually required *β´* modification and textural parameters *(Piska et al., 2006; Zárubová et al., 2010)*. Nowadays, the process of enzyme-catalysed randomization using specific sn-1,3 lipases has already been established. As saturated fatty acid sources, palm oil stearin fractions are used as a source of palmitic acid, palm kernel oil as a source of saturated C8-C18 acids with lauric and myristic acid dominance, or completely hardened vegetable oils (totally hardened palm oil contains only palmitic and stearic acids; totally hardened oils such as rapeseed, sunflower or soy oils contain mostly stearic acid - **Figure 9**).

The structural fats and final fat blends thus prepared do not contain TFA (their content is <1%). The physical properties of the product are a function of the saturated fatty acid content. Fat blends of reformulated margarines usually contain about 20-30% saturated fatty acids, while the original ones contained 20-35% of trans fatty acid isomers.

If the existing types of fat products such as spreadable fats, e.g.fats and blends, shortenings and fat foods, where these fat products are applied, have to be preserved, fat blends will have to be reformulated to substitute TFA with saturated fatty acids. This can be understood, within the meaning of current knowledge of nutrition reflected in nutritional recommendations, as the replacement of one risk factor with another, less risky one.

This basic process is followed by reducing the fat content of the products, or its replacement with carbohydrate or protein-based substitutes.

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Reformulating soft drinks

Čížková H., Grégrová A.

Types of drinks

The offer of soft drinks is very diverse. The most frequently consumed drinks include lemonades, flavoured mineral waters and fruit juices and nectars. At the same time, however, the popularity of non-carbonated or minimally processed drinks, drinks containing non-traditional ingredients (often presented as having some health benefit) and also drinks with low--sugar content or those produced with little or no additives, is increasing. The classification and characteristics of non-alcoholic drinks are defined in Decree No 248/2018, on requirements for beverages, vinegar and yeast.

The largest and most heterogeneous group of drinks are flavoured non-alcoholic drinks, which are further divided into the following subgroups:

- fruit or vegetable drink,
- lemonade,
- flavoured mineral water,
- flavoured spring water,
- flavoured drinking water.

The individual categories mainly differ in the flavouring component or the type of water used. Due to their sugar content and the presence of a number of additives, they are candidates for the possible reformulation of recipes.

The largest segment (almost 40%) in soft drinks is lemonades. They are made from drinking water and drink concentrates. The highest sales are enjoyed by cola-type lemonades and lemonades flavoured with orange and other citrus fruits. However, the fastest-growing segment is iced teas and energy drinks, which also belong to this group *(Czech Statistical Office Food Consumption, 2017; Expectations of Companies in Indicative Industries - Soft Drinks, 2014)*.

Flavoured waters are split into flavoured mineral, spring and drinking water, and are usually clear, colourless, sweetened, flavoured with appropriate flavourings, and optionally with the addition of fruit juice. At the same time, the labelling for flavoured mineral and spring water must contain information about the locality, the source name and the carbonation, if the water has been saturated with carbon dioxide *(Čížková, 2016)*.

Important raw materials for the production of the above drinks are fruit and vegetable semi-finished products and liquid (or powdered) drink concentrates. Their composition is highly variable and, in addition to flavouring and aromatizing components, they often contain sugars (syrups) and common additives.

Fruit juices and nectars, due to their natural origin, processing method and composition of micronutrients, represent a healthy alternative to other drinks. At the same time, however, they are significant sources of sugars, 9% to 16% by content.

Non-alcoholic drinks also include soda water; however, because of the focus of the present study, the requirements for soda water are not relevant.

Drink ingredients

The basic ingredient of all soft drinks is water, usually ranging from 88% (fruit juices) to 99% (for low-energy drinks - often called light, zero, sugars-free). Other common ingredients include sugars, plant (fruit, vegetable, herbal, tea, etc.) extracts and concentrates, flavourings and additives (sweeteners, acidity regulators and dyes, while some also contain stabilizers and preservatives) *(Čížková, 2016)*.

The type and quantity of additives that may be present in drinks, the conditions of use and the labelling of their presence on the packaging are laid down in the relevant legislation. However, the benefit of the additives for the general consumer is offset by a certain risk to sensitive or sick persons; for this reason, the additives listed below are candidates for restriction of use and reformulation. The aspartame sweetener (E951) must not be consumed by people with phenylketonuria metabolic disorder. The short-term acute effects of sulphur dioxide (E220 - E228) may manifest through dermatitis and allergies in susceptible individuals. Several other common additives (E210-E213 benzoates, E120 carmine, E102 tartrazine, azo dyes) are also known to provoke adverse reactions, mainly including skin and respiratory problems.

Increased consumption of coloured soft drinks containing blends or one of six selected colours (E102 tartrazine, E104 quinoline yellow, E110 sunset yellow, E124 ponceau 4R, E122 azorubin, E129 allura red AC) may lead to hyperactivity in young children according to some studies. Therefore, as a precautionary measure, since 2013 producers have been required to indicate on the product label a warning about the potential for adverse effects on children's activity and attention if used (Regulation (EU) No 1333/2008).

Sugars

In Central Europe, sugar (sucrose) from sugar beet is a traditional sweetener. Sucrose is used in the form of crystalline sugar or liquid sugar (usually 67 °Brix). Sugarcane as a source of sucrose or invert syrup (obtained by acid hydrolysis of sucrose to glucose and fructose at a 1:1 ratio) is rarely used in domestic drinks.

In addition to sucrose, which is the so-called gold standard in terms of both sweetness and sweet taste, glucose-fructose syrup (HFCS-42, usually 73 °Brix) has been used as a sweetener in recent years. It is produced by hydrolysis and subsequent enzymatic conversion from starch (most commonly corn) and is also known as isoglucose or high fructose corn syrup (HFCS). Advantages of this syrup compared to sugar are its lower price and easier handling; in the case of fructose-glucose syrup (i.e. HFCS-90 or HFCS-55) also the reduced likelihood of recrystallization and higher sweetness (i.e. the possibility of using less HFCS in the formulation, resulting in a correspondingly lower energy value).

Glucose syrups are also made from corn starch. They are often used in energy drinks and drinks for athletes, where high total sugar content and rapidly available energy at lower sweetness are required (the relative sweetness compared to sucrose is 0.6-0.7). Pure fructose (fruit sugar) or fructose syrup is produced in Europe from chicory root, has a sweetness higher than sucrose (1.1-1.7) and is used rarely, in energy-reduced drinks. Trehalose, isomaltulose and D-tagatose have also been permitted in selected drinks from 2001 to 2005, while polyols (e.g. sorbitol and xylitol) are not permitted in drinks in the EU *(Čížková, 2016; Ashurst et al., 2017; Belitz et al., 2009).*

In order to increase the sweet taste, other sugar-rich foods such as fruit juices, purees and concentrates, deionized fruit concentrates and possibly honey are also added to drinks *(Burgos et al., 2016)*.

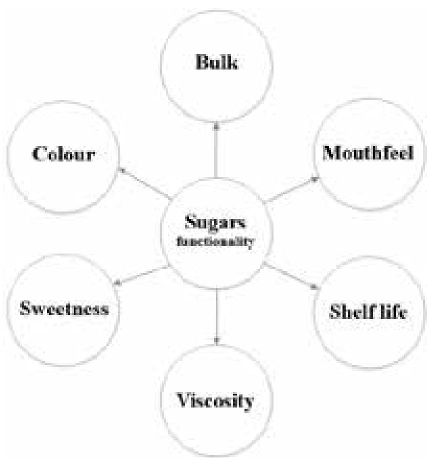
The results of a survey of the soft drinks market conducted in Germany in 2016 are summarized in Table 10 *(Huizinga, Hubert, 2017)*. A total of 463 non-alcoholic flavoured products (see above) available in the three largest retail chains were broken down by sugar content based on the definitions in the European (Regulation (EU) No 1924/2006) and British *(The Soft Drinks Industry Levy Regulations, 2018)* legislation.

Table 10: Number of non-alcoholic drinks available on the German market in 2016 broken down by sugar content per 100 ml (463 products in total) *(Huizinga, Hubert, 2017)*

Sugar content (per 100 ml) and optional labelling	Labelling with traffic-light colours by Soft Drinks Industry Levy Regulations 2018	Number of products
< 0.5 g (sugar free)	green	6 (no sweetener added), 49 (sweetener added)
0.6–5 g	yellow	134
5.1–8 g	orange	103
> 8 g	red	171

Sugars are usually the most common component in drinks after water. They are responsible for the sweetness of drinks, contributing to the texture and to the so-called mouthfeel by increasing the intensity of the overall perceived taste of the drink. At the same time, sugars promote colour stability, drink shelf life and form a barrier to the growth of spoiling microorganisms (Figure 10). All these functions and their possible limitations have to be considered in the possible reformulation of a recipe *(Burgos et al., 2016)*.

Figure 10: Functional properties of sugars in soft drinks (processed by *Burgos et al., 2016*)



Reformulation through reducing or replacing sugars

Non-alcoholic drinks are primarily important for maintaining liquid intake, i.e. for the sufficient hydration of the body. However, a number of non-alcoholic drinks are a significant source of energy, especially those derived from simple carbohydrates (sugars). In the case of sweetened drinks, the sucrose content or the corresponding amount of glucose and fructose is between 6% and 11%. Unsweetened fruit juices contain from 6% (strawberry, raspberry) to 16% (grape, plum, banana), and vegetable ones (carrot, tomato) from 3% to 6% (AIJN Code of Practice). The main concerns of nutritionists regarding the (excessive) consumption of some soft drinks arise from these facts. It has been confirmed that the high sugar content in drinks is, under certain conditions, associated with obesity, Type 2 diabetes and the risk of myocardial infarction *(Huizinga, Hubert, 2017; Ashurst, 2016)*. For example, according to a study by Malik et al. (2010), consumers who regularly consume 1 to 2 sugar-sweetened drinks daily are 26% more likely to develop Type 2 diabetes than those who drink these drinks rarely *(Malik et al., 2010)*.

One possible tool to reduce the consumption of sugars from sweetened drinks is to increase the tax burden. Countries that have taken this step (e.g. in Europe the United Kingdom, Belgium, Finland, France and Hungary) expect a decline in the consumption of these drinks, a response from producers leading to a reformulation of the drinks with less sugar and at the same time plan to use the financial revenues to support health and awareness programs. The WHO has also called for the taxation of sweetened drinks, as according to it a 20% or more price increase would have a demonstrable impact on consumption and hence on health *(Huizinga, Hubert, 2017).* The prediction model for the influence of taxation on drinks (Soft Drinks Industry Levy Regulations, 2018) with a sugar content of more than 5% on the health of the British population suggests a 0.5% to 0.9% reduction in obesity, fewer incidents of Type 2 diabetes (by 18-31 persons/100 000 inhabitants/year) and less denture defects (caries, losses, necessary repairs) by 2-4 persons/1 000 inhabitants/year *(Briggs et al., 2017)*.

Since most of the energy in drinks comes from sugars, reducing the sugar content is the only potential solution. Two ways of reformulation are being considered:

- the complete removal of sugars from the recipe and the possibility to use the nutrition claim “sugar-free” if the product contains no more than 0.5 g of sugar per 100 ml or “with no added sugar” (Regulation (EU) No 1924/2006),
- the partial removal of sugars from the recipe to produce “low sugar” products if the product contains no more than 2.5 g of sugar per 100 ml (Regulation (EU) No 1924/2006).

Neither of these practices is acceptable for 100% fruit and vegetable juices which, according to European legislation, may not be modified except for certain defined exceptions (Directive 2001/112/EC on fruit juices and certain similar products intended for human consumption).

Low-energy sweeteners

Low-energy sweeteners can provide a substitute for the sweet taste of sugars. Those most commonly used in drinks are acesulfame K (E950), saccharin (E954) and aspartame (E951), usually in various combinations, but cyclamates (E952), NHDC (E959 neohesperidin DC), neotam (E961) and sucralose (E955) are also permitted. New products that have appeared in recent years include natural steviol glycoside sweeteners (E960), obtained by extraction from sweetleaf (Stevia rebaudiana Bertoni) and further modified through a defined physical/chemical process *(Stávková, 2011),* and thaumatin (E957), a mixture of proteins isolated from the katemfe plant (Thaumatococcus daniellii Bennett), permitted only as a flavour enhancer (Regulation (EU) No 1333/2008). Typically, low-energy sweeteners are several hundred times sweeter than sucrose and do not increase (or only minimally in the case of natural sweeteners and aspartame) the energy value of the drink **(Figure 11 and Table 11)**.

Figure 11: Approximate relative sweetness of selected sweeteners; * in low concentrations, otherwise about 350 (processed according to *Nordic Sugar Member of Nordzucker Group, 2006*)

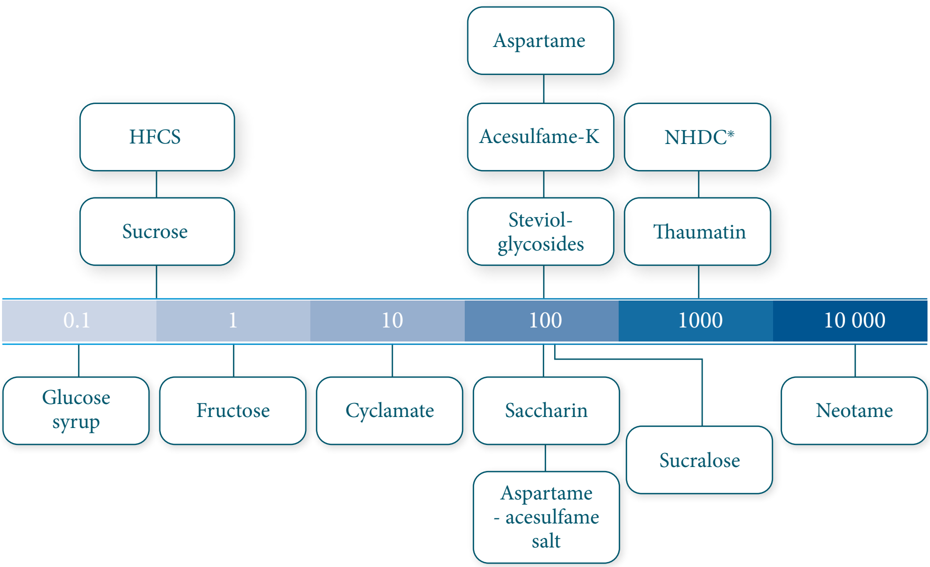


Table 11: Properties of low-energy sweeteners and rules for their use in drinks *(elaborated according to Ashurst, 2016, Regulation 1333/2008, EFSA, 2010, EFSA, 2007)*

Sweetener	E-code	Solubility (g/l)	Caloric value (kcal/g)	ADI (mg/kg)	Allowed in the EU	Allowed in the USA	Max amount (ppm)[a]	Relative sweetness[b]
Acesulfame-K	950	270	0	9	Yes	Yes	350	200
Aspartame	951	10	4	40	Yes	Yes	600	200
Cyclamate	952	200	0	7	Yes	No	250	35
Saccharin	954	3,700	0	2.5	Yes	Yes	80	400
Steviol Glycosides	960	1.2	0	4	Yes	No	80	70–300
Sucralose	955	280	0	15	Yes	Yes	300	450
Alitame	956	131	1.4	0.1	No	No	N/A	2,000
Neotame	961	13	0	2	Yes	Yes	20	8,000
Neohesperidin DC	959	0.5	0	5	Yes	No	30	300–600
Aspartame-Acesulfame Salt	962	23	2.6	c	Yes	Yes	350	350

a: in non-alcoholic drinks in the EU; b: 5% equivalent; sucrose = 1; c: including ADI for individual constituents (i.e. aspartame and acesulfame K).

At the same time, however, it should be borne in mind that low-energy sweeteners have an effect on the sensory properties of the drink as they taste differently to sucrose and may also have an aftertaste. While sucralose, cyclamate and aspartame have a flavour profile relatively close to sucrose, saccharin alone exhibits a bitter to metallic aftertaste similar to acesulfame K, but to a lesser extent *(Ashurst, 2016)*. The relative sweetness of sweeteners in drinks is non-linearly dependent on concentration and pH; e.g. the relative sweetness of saccharin decreases from about 500 (at a corresponding sucrose concentration of 1%) to 120 (at a corresponding sucrose concentration of 10%); for sucralose, the decrease is not so significant, but its sweetness is particularly strongly dependent on pH at lower concentrations (900 at pH 2.75 vs. 500 at pH 3.1) *(Belitz et al., 2009; Nordic Sugar Member of Nordzucker Group, 2006)*.

Since taste is a complex sense, the interaction of sweeteners with a sour taste and the change in the profile in the mouth over time after ingestion should be taken into account in reformulations. While the maximum sweet taste is reached within 10 seconds of consumption of sucrose and saccharin and then rapidly decreases, it reaches its maximum for NHDC and thaumatin after 20 seconds yet persists even after 1 minute *(Nordzucker Group, 2006)*.

These sweeteners also cannot take over additional functions of sugar in drinks, i.e. the mouthfeel (significant contribution at a concentration of 7-10%) and intensification of other tastes and flavours (e.g. fruit flavours). In the case of drink concentrates and syrups, sugars also function as microorganism growth inhibitors by reducing water activity and increasing osmotic pressure. Sugar substitution also affects the chemical stability of drinks, for example there is a risk of loss of taste and colour in acidic environments or after heat treatment *(Burgos et al., 2016)*.

The factors that need to be considered in relation to reformulations according to the "Reformulation guide for small to medium sized companies" study *(Burgos et al., 2016)* in the case of the selection of sugar substitutes and chosen dosage are as follows:

- Legislative requirements and health reservations. These are limits on additives (Regulation (EU) No 1333/2008), see the European Commission database: https://webgate.ec.europa.eu/foods_system/main/ and labelling requirements for food (Regulation (EU) No 1924/2006 and Regulation (EU) No 1169/2011); current scientific evidence suggests that the regular, heavy consumption of drinks with sweeteners is associated with the same increase in health risks connected to the consumption of excessive sugar, including Type 2 diabetes, cardiovascular disease, hypertension and stroke. From this point of view, a reduction in both sugars and sweeteners seems desirable to improve public health *(Swithers, 2016)*.
- Sensory acceptance for consumers. This is largely influenced by the original or traditional recipe, product type, expectations and habits. Although acceptability can be predicted to some extent, it is usually necessary to test each particular innovated formulation using both sensory and consumer preference tests. Table 12 shows the results of acceptability tests for different sweetener combinations in 2 types of non-carbonated flavoured drinks (raspberry and strawberry). The new formulations were prepared so that the theoretical sweetness was the same, while the variations with natural sweeteners always corresponded to a 40% reduction in energy compared to sweetening only with sugar *(Nordic Sugar Member of Nordzucker Group, 2006)*.
- Financial costs. Although, with some exceptions, the price of sweeteners – given their high sweetness and thus the low dosages required – is favourable compared to sugar *(Ashurst et al., 2017)*, on the other hand potential additional indirect costs resulting from the other factors listed here should be taken into account.
- Production technology options, stability and durability of substitutes. While most swee-

Table 12: Results of preference tests of different combinations of sugars and sweeteners (scale 1 - best, 8 - worst) *(Nordic Sugar Member of Nordzucker Group, 2006)*

Constituents	Raspberry drink – preference ranking	Strawberry drink – preference ranking
Sucrose (control)	4	3
Invert sugar, sucrose, aspartame	2	1
Invert sugar, sucrose, aspartame, saccharin	3	4
Invert sugar, sucrose, aspartame, saccharin, NHDC	1	5
Invert sugar, sucrose, aspartame, saccharin thaumatine	7	6
Glucose syrup, aspartame, saccharin, NHDC	5	7
Aspartame, acesulfame K	6	2
Aspartame, saccharin	8	8

teners are chemically stable for 12 months in a drink, aspartame decomposes gradually in an acidic environment and this is accelerated by inappropriate (higher) storage temperatures. Solutions are 1) a higher dosage in the recipe so that the minimum sweetness required is maintained throughout the shelf life, 2) the use of acidity regulators (e.g. sodium citrate), 3) mixing with another 1 to 2 sweeteners and taking advantage of synergy (for example, a 60% aspartame + 40% acesulfame K combination is common) *(Ashurst et al., 2017)*.

Partial sugar substitutes

The sensory and technological disadvantages of total sugar substitution with low-energy sweeteners can be compensated to some extent through the partial replacement of sugars, for example through the use of mixtures (e.g. sucrose + fructose + HFCS or glucose or sucrose + sweetener) in amounts and proportions giving the same sweetness but a lower energy value *(Burgos et al., 2016)*; see **Table 12** as an example.

Here again, the possible impact on the stability of the final product should be borne in mind. In particular, drinks with sensitive flavours (such as citrus flavours) are susceptible to oxidation with the use of lower quality (purity) sugars and sweeteners. Contaminants in the form of minor and trace elements in particular can cause undesirable changes. As a precaution, it is recommended to include a deionization step. During the production process, it is important to consider the different physical/chemical properties of the substitutes, which may result in lower solubility or the microbial instability of the ingredients *(Ashurst, 2016)*.

The same aspects should also be considered when complying with consumer preferences for switching from glucose-fructose syrup to sucrose when innovating drink recipes. The hydrolysis (inversion) of sucrose to glucose and fructose under acidic conditions cannot be neglected either. The reaction rate is dependent on both temperature and pH. 50% inversion occurs at a pasteurization temperature of 90 °C between 6 minutes (at pH 3) and 6 hours (pH 4.5), at 40 °C between 1 day (pH 2) and 100 days (pH 4.5). Long-term storage experiments with lemonade (pH 2.4) and fruit juice (pH 3.1) resulted in 90% and 40% conversion over 100 days *(Nordic Sugar Member of Nordzucker Group, 2006)*.

Reformulation for dental health

The high consumption of sweet and also acidic soft drinks together with a lack of dental hygiene is an important factor promoting changes in the microbial and biochemical composition of plaque and demineralization of the teeth (reduction in fluorine, calcium and phosphorus), which in turn leads to dental erosion and dental caries *(Caballero, 2016; Lukáčová, 2007; Grenby, 1996)*.

Various modifications to the drink recipes have been tested as protective factors. The first option is to reduce or replace the main components, i.e. (fermentable) sugars and acids. The reformulation options for reducing sugars are described above. In the case of acids (acidity regulators), which are among the most important factors in the development of dental erosion, their sensory and technological properties should again be considered. The erosive potential is determined not only by low pH (i.e. distribution by dissociation constant), but mainly by the amount in the product. From this point of view, apple juice (pH 3.3, malic acid content 4.5 g/l) has a higher erosion potential than a cola drink (pH 2.5, phosphoric acid content 0.6 g/l) or carbonated orange lemonade (pH 2.9, citric acid content 2 g/l) *(Lukáčová, 2007)*.

The addition of buffers to reduce the acidity of drinks appear to be ineffective or sensorially unacceptable for consumers, similarly to the proposal to neutralize the negative effect of the drinks by rinsing the oral cavity with a solution of baking soda (sodium bicarbonate).

On the other hand, research aimed at adding calcium phosphate and other soluble phosphates or calcium salts seems promising. Phosphates protect teeth from tooth decay by increasing phosphorus availability in plaque, thereby slowing demineralization and promoting remineralization; e.g. the addition of 2-2.5% calcium phosphate solution to acidic fruit juice in a model experiment significantly slowed tooth erosion.

Fluoride supplementation is generally used to increase the resistance of hard dental tissues as part of the caries prevention system.

For example, the addition of 2 ppm sodium fluoride significantly reduced the erosion potential of a fruit drink in laboratory animal experiments *(Grenby, 1996)*.

Reformulation by increasing added value

Drinks with added nutritional or health value include those with a high proportion of fruit or vegetables. They are sources of the protective substances contained in the ingredients, especially vitamin C, folic acid, potassium, magnesium and other substances with antioxidant and anti-inflammatory properties such as polyphenols, carotenoid pigments and others.

Another group is the so-called functional drinks. These are drinks which, in addition to water, contain nutritionally important substances with additional physiological effects and thus have a positive effect on health, physical performance or mental state. They are specifically enriched with functional ingredients such as fibre, oligosaccharides, sugar alcohols, amino acids, vitamins, minerals, natural extracts of herbs, tea, fruits, etc. Examples are superfruits (e.g. pomegranate, acerola, goji) and plant extracts (ginger, ginkgo). However, it should be borne in mind that the term functional drink (food) is not defined in European legislation and any declaration of positive preventive effects should comply with the legislative rules for nutrition and health claims.

Functional drinks include drinks for athletes with a balanced mineral content, designed to replace nutrients and liquids during sports or physical activity (ionic drinks). Other functional drinks are energy drinks that increase endurance, activity and concentration. They are listed under lemonades, but stand out in this subgroup precisely through the presence of functional substances such as caffeine, taurine, B-complex vitamins, vitamin C and plant extracts (guarana, ginseng, yerba mate, etc.) *(Čížková, 2016; Ashurst, 2016; Caballero, 2016; Kregiel, 2015)*.

However, the recommendations relating to reformulation through reducing or replacing sugars also apply to these products. The results of energy-drink market surveys conducted in the United Kingdom in 2015 (75 products) and 2017 (49 products) are summarized in **Table 13** and show that many drink producers carried out reformulation between these dates - on average, a decrease in the content of sugars by 10% and of energy by 6% was found, while caffeine content

Table 13: The content of sugar, caffeine and energy in energy drinks *(average and range, comparison of changes between 2015 and 2017) (Hashem et al., 2017)*

	2015 (75 products)	2017 (49 products)
Sugar (g/100 ml)	10.6 (1.9–15.9)	9.7 (2.1–16.0)
Energy value (kcal/100 ml)	47 (10–70)	44 (10–70)
Caffeine (mg/100 ml)	29.4 (0–32)	31.6 (30–32)

remained at the same level *(Hashem et al., 2017)*.

Technological constraints on reformulation

Innovation in the production process and recipes influences, among other things, the shelf life of drinks. The cause is most often reduced microbial stability of the drink or the introduction of new, resistant species of microorganisms from inadequately specified or exotic ingredients. The most well-known indicators of spoilage include

Table 14: The most common defects of soft drinks caused by microorganisms *(Juvonen et al., 2011)*

Spoilage microbe	Off-flavours / odours	Visual spoilage	Metabolites
Yeasts	Vinegar, pineapple note, butter, petroleum-like odour	Swollen packages, tainting, clouds, surface films	CO_2, ethanol, acetic acid, diacetyl, acetaldehyde, esters, 3-hydroxybutan-2-one, 1,3-pentadiene, exocellular polysaccharides
Lactic acid bacteria	Cheesy notes, sour, green apple	Loss of CO_2, ropiness, turbidity	Lactic acid, CO_2, ethanol, acetic acid, diacetyl, formic acid, exocellular polysaccharides
Acetic acid bacteria	Sour, vinegar	Haze, swollen packages, ropiness	CO_2, gluconic acid, acetic acid, ethyl acetate, acetoin
Alicyclobacillus spp.	Antiseptic and smoky taints	Difficult to detect	2,6-dibromophenol, guaiacol
Moulds	Musty, stale	Mycelial mats, discoloration, swollen packages	Pectin degradation, formic acid, increase in pH, gas production, gluconic acid

Figure 12: Microbiological defects caused by product innovation without sufficient consideration of factors affecting drink stability *(photo: Iveta Horsáková)*

Flavoured, carbonated mineral watter with added preservatives: formation of micelial mats by *Penicillium* spp.

Green tea, pasteurized: sediment of *Gluconobacter sp.*

Green tea, pasteurized: surface contamination by *Asaia* sp.

Lemonade with added preservatives: formation of micelial mats by *Penicillium* spp. and petroleum-like odour caused by microbial decomposition of sorbate sensory defects such as unsatisfactory appearance (e.g. turbidity, sediment, floating particles, gas production) or atypical smell and taste **(Table 14 and Figure 12)** *(Šístková et al., 2015)*.

Flavoured soft drinks are generally considered to be resistant to microbial spoilage. This resistance is due to low pH (2.5-4.5), the anaerobic conditions in carbonated drinks, the antimicrobial action of essential oils (citrus lemonades) and the relatively low content of substances microorganisms can use as nutrients *(Šístková et al., 2015)*. These conditions, together with specific preservation procedures, are necessary obstacles ensuring product stability.

However, the above-mentioned possibilities for reformulation may influence some of the key factors affecting the survival and growth of microorganisms *(Azeredo et al., 2016; Juvonen et al., 2011)*:

- pH and acidity. The risk of spoilage, including pathogen growth, increases with increasing pH; tolerance of acidic environments in drinks decreases in the following order: moulds and yeasts, alicyclobacilli, lactobacilli, acetic acid bacteria and leuconostocs. Modifying a recipe to pH 3.5 to 4 by changing the acidity regulators or adding low-acid exotic juices (e.g. melon, papaya, acai, cantaloupe) is risky.
- Carbonation and oxygen availability. Most spoilage microorganisms (except for e.g. *Saccharomyces* and *Dekkera* yeasts) require an aerobic environment, so carbonated drinks are less prone to spoilage. The partial or complete elimination of drink carbonation or the use of packaging with higher oxygen permeability is risky.
- Nutrients. In general, all ingredients that can provide nutrients for microorganisms increase the sensitivity of the product. Drinks enriched with fruit and vegetable juices are among those with a complex and highest nutrient content. The presence of sugars is needed for the growth of yeast, while a reduction in sugar content from 10% to 5% does not provide an inhibitive effect – only complete replacement with low-energy sweeteners does.
- Functional components. These need to be assessed individually. Some have antimicrobial effects (plant extracts, essential oils) while others are a source of nutrients for undesirable microorganisms (B-complex vitamins, calcium lactate, cereal extracts, beta-glucans, taurine) or may be the primary cause of unexpected microbial contamination.

It follows from the above that any reformulation involving any component or factor affecting microbial stability should include adequate replacement and/or verification of the shelf life of the new drink.

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Reformulation of fruit and vegetable products

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Fruits, vegetables and related products are often perceived by consumers as "healthy" and consumable in virtually any quantity. However, consumption should be approached with care in the case of fruit and especially fruit products. Fruit products (compotes, fruit spreads, candied fruits etc.) often have a high sugar content, while some vegetable products are significant sources of salt. Efforts to reformulate are therefore also meaningful for these products.

Characteristics of fruits and vegetables and the classification of products from them

From the perspective of the consumer or the food industry, fruit is generally characterized as the edible fruit of a plant or tree that includes the seed(s), the container, and can typically be described as sweet and juicy *(Kandasamy, Shanmugapriya, 2015)*. Both technologists and consumers traditionally regard fruit as the edible fruits, infructescence and seeds of various perennial cultured or wild trees and herbs. Fruit is characterized by a sweet taste and is often consumed only in an untreated state. Vegetables can be defined as different parts of edible plants, except fruits. However, this breakdown does not completely cover the whole range of fruits and vegetables, and it is also possible to find species that cannot be clearly classified in one of the above-mentioned groups *(Sluková et al., 2016)*.

Fruit and vegetable products represent a very wide range of products which can be classified in several ways based on the consistency of the final product (lumpy, crushed, liquid), or according to the method of preservation for chilled, dried, sterilized, frozen, glazed, chemically preserved products etc. Like fruit, vegetables are processed into a wide range of products differing in both consistency and preservation method. A basic overview of fruit and vegetable technologies is shown in **Figure 13.** A number of preservation procedures are applied in the processing of fruits and vegetables and the range of final products varies greatly. The advantages and disadvantages of selected technological and preservation procedures are described in the relevant literature *(Sluková et al., 2016; Barrett, Somogyi et al. 2004; Hui, 2004 Jongen, 2002)*.

Fruits, vegetables and health

The onset and progression of some diseases are clearly influenced by lifestyle. Nutrition is one of the most important factors affecting human health and it is increasingly mentioned in literature that a diet rich in fruit and vegetables can have a positive effect on health. Ancient medicine prescribed a combination of fruits, vegetables, nuts, herbs, spices and their extracts to treat certain diseases. Although some mechanisms for these positive effects of fruit and vegetables on health have not been fully clarified, secondary metabolites in fruit and vegetables commonly referred to as phyto compounds *(Miller et al., 2017)* could play a role. The positive health effects of eating vegetables and fruit are mainly attributed to the following ingredients: vitamins, minerals, fibre, flavonoids, glucosinolates, carotenoids, phytoncides etc. *(Hord et al., 2009, Sluk et al., 2016)*. However, fruit and vegetables also contain substances that adversely affect the consumer's health such as oxalates, nitrates, alkaloids, strumigens, cyanogenic glycosides and others *(Sluková et al., 2016)*. More and more studies show that the low consumption of fruit and vegetables is associated with the development of some diseases such as cancer, stroke, diabetes and hypertension *(Roark, Niederhauser, 2012)*. The WHO defines the consumption of less than five portions of fruit and/or vegetables per day as low fruit and vegetable consumption, with the equivalent of one portion being approximately 80 g. The WHO panel dealing with diet, nutrition and the prevention of chronic diseases recommends the intake of at least 400-600 g of fruit and/or vegetables in 5-8 portions per day *(WHO and FAO, 2003, Hall et al., 2009)* to reduce the risk of micronutrient deficiency, cardiovascular disease, cancer, cognitive impairment (memory, concentration, attention, speech, information processing rate etc.) Epidemiological studies show that the consumption of fruits, nuts and vegetables affects the occurrence of cognitive dysfunctions related to aging *(Miller et al., 2017)*. Up to a third of fruit and vegetables are peel, core etc., which are a rich source of fibre, and in particular the by-products of fruit and vegetables such as juices and drinks are gaining attention as new and economic resources, not only fibre *(Rodríguez et al., 2006, O'Shea et al., 2012)*.

Fruits and vegetables are characterized by high water content and, compared to other food raw materials, generally a lower content of basic nutrients and thus a low energy content. A low energy value is typical for vegetables; while fruit has a higher energy value due to its sugar content *(Sluková et al., 2016)*. There are some exceptions to the above, for example lipid-rich avocados or dry nuts. Fresh fruit contains 75-95% water, which also explains its refreshing character *(Kandasamy, Shanmugapriya, 2015)*. Vegetables have always had their place in the diet thanks to their vitamin (especially vitamins A and C), minerals and phytocompounds content. In addition, they are recommended as a source of fibre *(Slavin, 2013)*. Significant nitrogenous substances from fruit and vegetables include proteins (35-85% of all nitrogen), the rest being free amino acids, peptides and other compounds. Other important proteins from fruits and vegetables are enzymes that act both positively and negatively in processing. Carbohydrates, including fibre, account for more than 90% of fruit's dry matter. Mature fruit contains mainly sugars, while vegetables contain low quantities of simple sugars. Depending on many conditions, the sugar content may vary considerably within a single fruit species. The main fruit monosaccharides are fructose and glucose, the characteristics of which are typical for the given fruit species. Other monosaccharides are, for example, galactose, arabinose and xylose, found only in some fruits. Selected fruits such as plums, pears and cherries also contain, for example, sorbitol which has laxative effects. Among the oligosaccharides, sucrose is the most abundant in fruit while other disaccharides such as maltose, melibiose and raffinose are present in negligible amounts. Among the polysaccharides, starch is also present in fruit and is degraded during the ripening of the fruit. Fruit and vegetables are important sources of fibre, especially pectin, cellulose and hemicellulose. The content of lipids is usually very low to negligible in fruit and vegetables, with one exception being avocados (12-16%). Generally, fruit has a low pH in the range of 2.5 to 4.4. Citric acid, malic acid and tartaric acid are the most common acids in fruit. Most fruits are a very good source of vitamins A, C, E, K and B, as thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6) and folate (B9). Fruit also contains flavonoids such as β-carotene, lycopene, cryptoxanthin, zeaxanthin and polyphenolic compounds. Fruit is also a good source of minerals such as sodium, potassium, phosphorus, iron, copper, calcium, magnesium and zinc *(Kandasamy, Shanmugapriya, 2015; Sebastian et al., 2002)*. The content of individual minerals in selected fruits and vegetables depends on the composition and properties of the soil, the intensity and manner of fertilization, climatic conditions and ripeness *(Sluková et al., 2016)*.

Table 15: Glycaemic index of selected fruit species – the GI of glucose, sucrose and white bread are listed for comparison *(Omolola et al., 2017, Kasper, 2015)*

Kind of food	Glycemic index (dried)
Glucose	100
Sucrose	59
White Bread	69
Lentil	29
Apple	40–44 (29)
Apricot	34–57 (30–32)
Banana	46–70
Mango	41–60
Orange	31–51
Peach	28–56 (35)
Pear	33–44 (43)
Pineapple	43–66
Plum	39 (29)

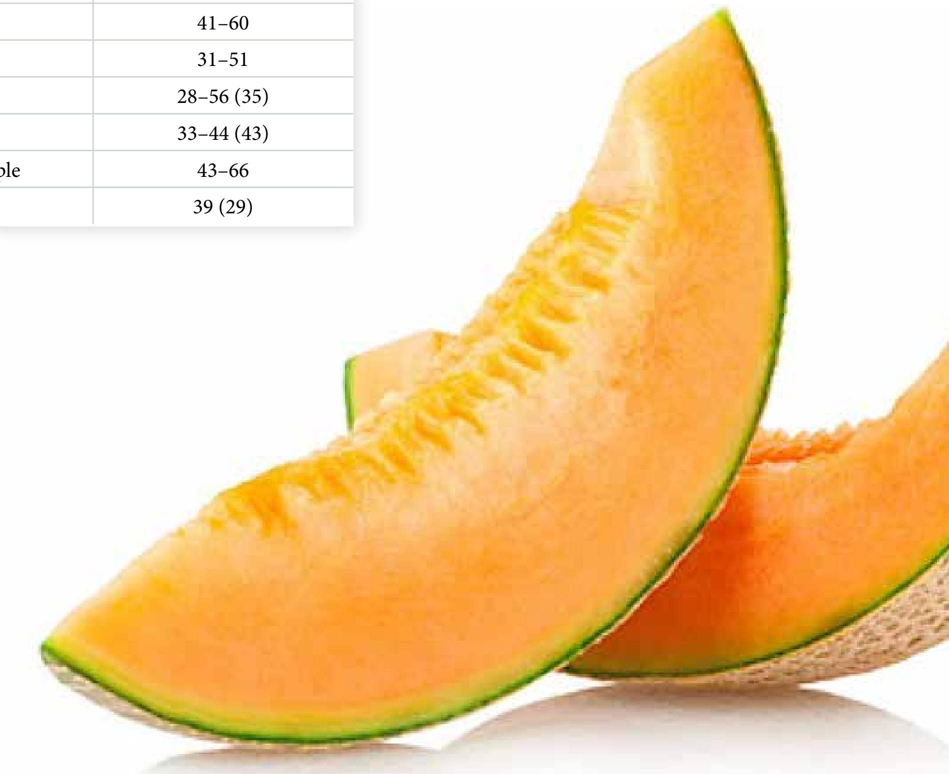
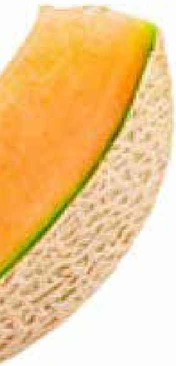


Table 16: Average carbohydrate content in different types of fruit
(Bownlee and Hammes, 1992, Souci, 2000)

g of sugar per 100 g of consumable portion			
	glucose	fructose	sucrose
Apples	1.4–2.4	4.8–6.4	0.5–2.8
Pears	1.5–1.7	5.6–7.7	1.1–2.5
Oranges	1.8–2.4	2.4–3.0	3.2–4.3
Tangerines	1.1–1.7	1.3	5.1–7.1
Grapefruits	2.1–2.8	0.8–2.4	1.7–4.6
Peaches	0.7–1.5	0.9–1.8	4.5–6.8
Apricots	1.0–2.9	0.4–1.6	3.6–6.0
Plums	2.2–3.4	1.2–2.0	3.4–5.2
Cherries	5.3–7.8	4.2–7.1	0.2–1.3
Strawberries	1.9–2.3	2.1–2.4	0.1–1.5
Raspberries	1.1–2.6	1.8–2.9	0.1–1.5
Blueberries	2.3–5.0	3.1–5.2	0.2–0.3
Grapes	4.0–9.0	3.9–9.3	0.2–1.6



Selected processes in food processing

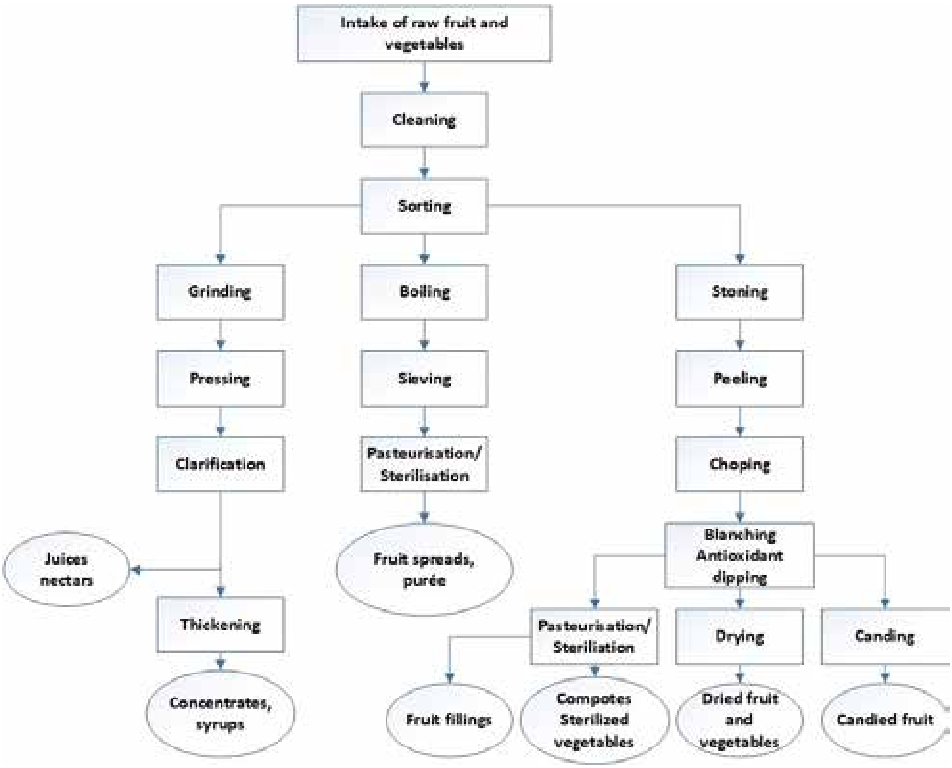


Figure 13: Overview of individual fruit and vegetable products and final products (taken and modified *(Sinha, et al., 2012)*

Due to the limited shelf life of most fruits and vegetables, this commodity has traditionally been available for a very limited time. A large amount of fruits and vegetables consumed today are processed *(Slavin, Lloyd, 2012)*. Attention should be paid to the sensory properties of reformulated products, since the consumer expects the products to have their typical characteristics and, for example, a sweet taste is often typical for the product (fruit spreads, candied fruit, etc.)

Possibilities for reformulation

At the end of 2011, the global population had reached seven billion. This figure is projected to increase by another billion by 2025 and yet, in the 21st century, around one billion people are starving and another billion are suffering from a lack of micronutrients. On the other hand, more than a billion people are overweight or obese, increasing the risk of associated diseases. Even with sufficient energy intake or its excess, the foods consumed can be a poor source of essential nutrients. There are opportunities to improve the nutritional profile and sustainability of the diet throughout the food chain from farm production, through retail to households. These include crop diversification, food enrichment, improved transport efficiency, waste minimization and, last but not least, food reformulation *(Buttriss, 2013)*. The food industry has two main alternatives for product reformulation: a gradual reduction of nutrient content without introducing further changes in the product recipe, or the partial/total replacement with other nutrients such as hydrocolloids, fat substitutes and sweeteners *(Aresa et al., 2018)*. The second approach compensates for some of the sensory changes caused by reductions in the nutrient content and can therefore lead to greater and faster content reduction. On the other hand, some studies have shown that products with no added salt or sugar are negatively assessed from a sensorial point of view *(DuBois, Prakash, 2012; Phelps et al., 2006)*.

Carbohydrates

Sugars added to foods during processing, preparation or “at the table” are considered added sugars. They contribute to the energy value of the diet but have little nutritional benefit, while a high intake is associated with increased energy content, dental caries and other undesirable health consequences such as excessive weight gain and reduced bone density. The current WHO recommendation states that the intake of added sugars should be less than 10% of the total energy intake *(Yeung et al., 2017; WHO, 2015)*.

Growing concerns about health associated with higher rates of obesity, metabolic syndrome and diabetes have resulted in increased interest in low-sugar foods *(Souza et al., 2013)*. Reducing the intake of simple sugars is recommended for the treatment and prevention of obesity, the prevention of dental caries and for many other reasons *(Bakr, 1997)*.

Different fruits naturally have very different carbohydrate content, in particular glucose, sucrose and fructose, metabolised independently of insulin *(Kasper, 2015)*. With increased consumer interest in reducing sugar intake, food products made using sweeteners are becoming more popular *(Dostálová et al., 2014; Souza et al., 2013)*. Sweeteners, apart from having to be safe and permitted by applicable legislation, must also be compatible with the food in question. The greatest possible emphasis is placed on sweeteners with the characteristic taste of sucrose, since replacing sucrose with sweeteners can cause changes in the perception of bitter and sweet tastes *(Pinheiro et al., 2005)*. Some sugar alternatives used have limitations such as legislative requirements, gastrointestinal consequences associated with high polyol intake and, last but not least, some consumer opposition to foods containing a lot of additives (the "desire for clean labels", meaning a minimum lists of ingredients) *(Buttriss 2013)*. Replacing sugar in reformulated foods could be a viable strategy for reducing sugar intake in the population without the need for a dramatic change in diet. However, reducing the sugar content of foods is difficult because of changes in taste, texture, functionality, shelf life etc. *(Cruz et al., 2010; van Raaij et al., 2009)*. The hygroscopic nature of sugar plays a vital role in reducing water activity in food and helps maintain and prolong food shelf life. For example, sugar prevents the microbial spoilage of jams after opening. It also helps preserve the colour of frozen fruit. So far, no sweetener has been developed that can fully duplicate all the functional properties of sucrose. It is therefore necessary to always understand the function of sucrose in a particular food product prior to its replacement **(Table 17)** *(Goldfein, Slavin, 2015)*.

Table 17: Carbohydrate functions and potential ways to reduce their content
(Buttriss 2013)

Function	Alternative approaches
Sweetness	high intensity sweeteners, polyols
Mouthfeel/ Texture	hydrocolloids, polyols and other sugars
Bulk	bulking agents, polyols, dietary fibre
Colour	additives
Flavour	additives
Stability/ Preservation	additives
Fermentation Substrate	–

Sweeteners

A sweetener is a food additive (hence it has also an E code) with a sweet taste derived from natural sources **(Table 18)** or made purely synthetically **(Table 19)**. Pursuant to legislation, sweeteners are additives whose use is governed by Regulation (EC) No 1333/2008. Legislation identifies foods to which sweeteners can be added and some other conditions of use. The term natural sweeteners is then commonly used for sweet carbohydrates, i.e. sugars. Sweeteners replace the taste of sugar and the term “substitute” or “synthetic” sweetener was used for these substances in the past. Sweeteners are further broken down into bulk sweeteners, including non-negligible sugar alcohols, and intense sweeteners with virtually negligible energy value. Every sweetener has certain advantages and disadvantages when used and it is often appropriate to apply a combination of sweeteners for a synergistic sweet taste effect, where the flavour and taste intensity are increased or the aftertaste found when using a single sweetener masked. Intense sweeteners have greater sweetness and are typically used in much smaller quantities than sugar, thereby contributing to a change in viscosity and density. For this reason, other additives such as hydrocolloid gums, which act as fillers or viscosity enhancers *(Sinchaipanit et al., 2013)*, are used in their application. Some consumers view sweeteners as very controversial and reformulation efforts need to be considered *(Varzakas et al., 2012; Tandel, 2011)*.

Every sweetener has a relative sweetness value, expressed in relation to sucrose (with a sweetness value of 1). A large number of studies have been published on sweeteners, especially synthetic ones, with conclusions ranging from “safe in all conditions” to “dangerous at any dosage”. Scientists are somewhat inconsistent in their views on synthetic sweeteners. The sweeteners used today are permitted additives and, according to the current state of knowledge, are completely safe *(Tandel, 2011)*.

Table 18: Natural sugar substitutes *(Tandel, 2011)*

Natural sugar substitutes	Potency (Times sweeter than sucro-se- by weight)	Potency (Times sweeter than sucrose- by food energy)
Brazzein	800	–
Curculin	550	–
Erythritol	0.7	14
Glycyrrhizin	50	–
Glycerol	0.6	0.55
Hydrogenated Starch Hydrolysates	0.4–0.9	0.5–1.2
Inulin	–	–
Isomalt	0.45–0.65	0.9–1.3
Lactitol	0.4	0.8
Lo Han Guo	300	–
Mabinlin	100	–
Maltitol	0.9	1.7
Maltooligosaccharide	–	–
Mannitol	0.5	1.2
Miraculin	Does not taste sweet by itself, but modifies taste receptors to make sour things taste sweet temporarily.	
Monatin	–	
Monellin	3000	–
Pentadin	500	–
Sorbitol	0.6	0.9
Stevia	250	–
Tagatose	0.92	0.24
Thaumatin	200	–
Xylitol	1	1.7

Table 19: Synthetic sugar substitutes
(Kroger et al., 2006, Tandel, 2011)

Artificial sugar substitutes	Potency (Times sweeter than sucrose- by weight)
Acesulfame K	200
Alitame	2000
Aspartame	160–200
Salt of Aspartame–Acesulfame	350
Cyclamate	30
Dulcin	250
Glucin	300
Neohesperidin Dihydrochalcone	1500
Neotame	8000
Saccharin	300
Sucralose	600

Possibilities for reformulating fruit and vegetable products

The possibilities for reformulating juices are limited in particular with regard to the applicable legislation and technological constraints. There is greater opportunity for reformulation in the case of nectars or fruit drinks, where the fruit content is lower. The issue of drinks is discussed in the chapter Reformulation of Soft Drinks. In a study by *Sinchaipanita et al., (2013)*, carrot juice was produced with various combinations of sweeteners (acesulfame K, aspartame and sucralose). All the sweetener samples had lower refractometric dry matter (6.2-6.4 °Brix) compared to the sucrose-sweetened standard (10.4 °Brix). The sweetener samples also had a lower pH (3.03-3.05) compared to the standard (3.38) and higher titration acidity (3.0-3.2 g/kg) compared to the standard (2.7g/kg). The sensory properties of the sweetener products were good *(Sinchaipanit et al., 2013)*.

In a study by *Rubio-Arraeze et al., (2017)*, low-sugar lemon marmalade was produced. The ingredients commonly used to make this marmalade are lemon pulp, sucrose and a gelling agent. In this study, isomaltulose and tagatose (39.9% tagatose, 39.9% isomalt, 0.02% sucralose, and 20% fibre) were used as sweeteners. A control marmalade with no sucrose substitute, marmalade A containing 60% isomaltulose and 40% tagatose, marmalade B containing these two sweeteners at a 50:50 ratio, and marmalade C with 30% isomaltulose and 70% tagatose were made. It was found that the reformulation of lemon marmalade using these sweeteners is possible. Although the marmalades with substitute sweeteners did not achieve such refractometric dry matter as sucrose marmalades, they were microbially stable throughout their shelf life (60 days). The combination of sweeteners used did not fundamentally change the viscoelasticity, which was lower than that of the control sample. The jelly with a higher proportion of isomaltulose initially had high luminosity compared to the other samples and browning occurred during storage *(Rubio-Arraez et al., 2017)*.

In a study conducted by *Rubio-Arraeze et al. (2015*), an orange marmalade was made using 60% orange pulp, 40% sucrose or sweeteners (39.9% tagatose, 39.9% isomalt, 0.02% sucralose and 20% oligofructose) and 1% agar. A control marmalade with 100% sucrose, marmalade A with 50% oligofructose and 50% tagatose, marmalade B with 30% oligofructose and 70% tagatose, and marmalade C with 70% oligofructose and 30% tagatose were produced. The marmalade with the same proportion of sweeteners was more consistent and showed an increase in elasticity over time. All the samples showed microbial stability over their shelf life. The evaluators' overall acceptance and intent to buy the marmalades was higher for marmalades with sweeteners than for the marmalade containing only sucrose *(Rubio-Arraez et al., 2015)*.

A study by *Mendoncla et al. (2001)* focused on the preparation of peach compotes with the partial replacement of sucrose with low-energy sweeteners. Sucralose was used as sweetener and acesulfame K in combination with sucralose were also used for comparison. To make the compotes, a 3.1% (w/v) sucralose solution, 100% acesulfame K in its solid state, sucrose and glucose were used. The peaches were weighed into 800 ml jars after preparatory operations to ensure that the peaches were always the same, and the jars then filled with an infusion at 100 °C. A solution of sucrose and glucose (w/w) in water with an initial concentration of 30 °Brix was prepared as a control. Three other solutions were prepared by substituting 30% sugar with the equivalent of low-energy sweeteners. First, a 19 °Brix sucrose-glucose solution was prepared and the sweetness was supplemented with sucralose (0.0189%), acesulfame K (0.0385%) and the mixtures thereof at a 1:1 ratio (0.0094% of sucralose and 0.0192% of acesulfame K). The reduction in the energy value with the sweetener substitutes was approximately 28%. Significant differences were found between these four formulas, especially in taste and acidity. The use of sucralose alone provided the peach compote with sensory characteristics similar to conventional peach compote. The compotes were stable over the shelf life (90 days) and showed partial sucrose inversion. In terms of sensory properties, there were significant changes in flavour and colour in particular. Compared to the sweetener substitutes, the control sample showed significant changes in taste characteristics compared to the samples with alternative sweeteners *(Mendoncla et al., 2001)*.

A study by *Akesowan (2010)* examined the stability of canned low-sugar mango with acesulfame K and aspartame. Slices of mango (1 kg) were placed in jars (1 l), then filled with a 35% sugar solution and left for 24 h. Thereafter, the syrup was emptied and the jar refilled with a new 40% syrup. The mango preserved in this manner was packed in a polypropylene bag and stored at 4-5 °C. The mango:sugar ratio was 1000:680 g. The low-sugar samples were prepared by replacing 30% of the sugar with an equivalent low-calorie sweetener to give the original sweetness (acesulfame K and aspartame in a 1:1 mixture). It was found that the combination of these two sweeteners provided a synergistic effect to maximize the sweet taste. The control and the low-sugar samples showed slight differences in physical/chemical and sensory properties over 6 weeks of storage at 4-5 °C. Samples with the 1:1 combination of acesulfame K and aspartame were most preferred with a 30% reduced sugar content, resulting in a reduction in total energy value of about 24% compared to the control. The microbial safety of these samples was about 4 weeks under the indicated storage conditions *(Akesowan, 2010)*.

Salt

Salt is the commonly used name for sodium chloride, consisting of 40% by weight of sodium and 60% by weight of chlorine, and accounts for about 90% of the sodium intake in the diet *(Kloss et al., 2015)*. Thus, based on the molar mass, the sodium content is multiplied by 2.5 × the equivalent sodium chloride content or, in other words, the sodium content in the diet is about 40% of the total salt intake *(Cohen, Alderman, 2007)*. The usefulness of salt for food preservation was already known in ancient Egypt, the Middle East and ancient Rome. Salt is used in many foods to improve the sensory properties and stabilize different types of products such as fish, eggs, bread, meat and vegetables *(Bautista-Gallego et al., 2013)*. Sodium is a biogenic element needed to maintain the cell membrane potential and for the absorption of nutrients in the small intestine. Furthermore, its presence maintains the volume of extracellular fluid, thereby maintaining blood volume and blood pressure. Excessive consumption of sodium is associated with negative health effects, of which the most alarming is increased blood pressure *(Kloss et al., 2015)*. It is believed that approximately 26% of the world's adults suffer from hypertension *(Allison, Fouladkhah, 2018)*. It is estimated that 62% of strokes and 49% of ischemic heart disease events are caused by high blood pressure. Excessive sodium consumption is also associated with a number of other adverse health effects, including gastric cancer, decreased bone mineral density and possibly obesity *(Liem et al., 2011)*. The large amounts of salt (9-12 g/day) consumed by populations in most countries of the world are now considered a serious health problem, and the World Health Organization (WHO) has initiated a global movement in response to the urgency of reducing sodium intake. In 2013, all member states agreed with the target of a reduction in salt intake by 30% to achieve a salt intake of less than 5 g/day by 2025 *(WHO; Zganiacz et al., 2017)*.

In industrialized countries, approximately 75-80% of the salt in the diet is consumed through processed foods, 5-10% of the salt is present in natural foods and 10-15% is the salt added during cooking or "at the table" (Kloss et al., 2015). Sodium is a major contributor to enhancing the palatability of food by increasing salinity and overall taste, by enhancing the flavour intensity of aromatic compounds through cross-interaction while suppressing bitter taste *(Dötsch et al., 2009)*. With respect to the salty taste, human receptors are able to adapt to low salt concentrations over time and a small, gradual reduction in sodium content in processed foods cannot be detected sensorially and thus represents one way to reduce sodium in the food chain. However, an effective change in sodium intake in the population in this way would require the collaboration of all competitors in the market, such as the simultaneous reduction of salt content in a particular product type *(Pioneer et al., 2004)*.

Because sodium reduces the activity of water, thus inhibiting the growth of pathogenic and sporulating microorganisms such as Listeria monocytogenes and Clostridium botulinum, a significant reduction in salt content must be compensated for through the addition of additional antimicrobial agents to ensure food safety and shelf life *(Kloss et al., 2015)*.

Sodium chloride may in part be replaced by potassium chloride or organic salts such as lactates, propionates, sorbates and benzoates without any major change in product properties *(Kloss et al., 2015)*. Chloride salts as sodium chloride substituents include potassium chloride, calcium chloride, magnesium chloride and zinc chloride *(Bautista-Gallego et al., 2013)*.

Salt preserves foods in the following ways:

1. by removing water from food and dehydrating it
2. by changing osmolarity, the internal processes of the cells change, causing microbial death
3. the presence of salt in high NaCl content products reduces the water solubility of oxygen, limiting the growth of aerobic microorganisms *(Bautista-Gallego et al., 2013)*

While unprocessed foods typically contain low sodium levels, processed food products are major contributors to the dietary sodium intake, up to about 75% of sodium in the adult American diet. Lower formulation costs, positive effects on food organoleptic properties, the effect on food quality during storage and microbiological safety make sodium chloride an important candidate and indispensable part of the formulation of various products *(Lopez Lopez et al., 2004)*.

Salt reduction in vegetable products

Vegetable products are an important source of sodium, but the impact of the consumption of these products on sodium intake among consumers is mostly small as these products are usually consumed only in limited quantities. The salt content of vegetable products is shown in **Table 20**. Traditionally fermented vegetables are processed using saline solutions. As a result, sodium is one of the macro-components of the final product. In reducing the sodium content of these products, the first step would consist of using a minimum amount of salt compatible with proper preservation and conventional sensory properties *(Lopez Lopez et al., 2004)*. In the particular case of Spanish-type olive processing, the fruits are treated with an NaOH solution, and excess hydroxide is removed by repeated washing. The olives are then placed in a sodium chloride solution. In this case, the use of other chloride salts such as KCl, $CaCl_2$ or $ZnCl_2$ could be promising *(Garrido Fernandez et al., 1997)*. Before placing a new product on the market, it is necessary to assess the acceptability of the product by the consumer using an expertly trained panel. For example, partial salt substitution using $CaCl_2$ and KCl in green table olives resulted in a product with a reduced salt content and acceptable sensory properties *(Di Silva, 2000)*.

Table 20 : The average salt content of various types of fermented vegetables on the market *(Bautista-Gallego et al., 2013)*

Product	Salt content (mg/100 g)
Olives	1156
Sauerkraut	661
Pickled Picles	1208
Boiled Carrot With Salt	302
Red Pepper, Chilli Canned	1173
Kimchi	641
Capers	2769

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Conclusion

Given the current rising trend of obesity and related lifestyle diseases, it is expected that interest in changing food recipes will increase. It is important to realize that poor eating habits that lead to overweight and obesity are a complex problem related to social difficulties, heath deterioration, an increase in the likelihood of developing other diseases and an overall reduction in quality of life. Excessive salt consumption is another important nutritional problem, especially with regard to cardiovascular disease.

Food producers are responding to these nutritional problems by changing the formulations of their products, but any recipe change is a demanding process involving not only the production of the reformulated product itself, but also re-evaluation of the product's shelf life or marketing studies to determine whether the product will be accepted by the consumer. When changing food product formulations, technological procedures must often be optimized so that the product can be produced, which can often result in the need to make investments in production equipment.

Consumers are actually often open to new trends in the food industry (e.g. insect consumption, etc.), but in the case of traditional foods, they expect their composition and production processes to be unchanged and perceive the use of certain additives, for example, very negatively. It therefore appears that the success of reformulation will also depend on appropriately chosen marketing so that the consumer positively adopts the reformulated product and does not perceive it as a kind of falsification. Some legislative constraints preventing attempts to reformulate some products are also worth mentioning. The sensory characteristics of new products, where reformulated products must also be sufficiently attractive to consumers in terms of their sensory qualities, also play a key role in reformulation.

The food industry cannot of course solve the nutritional problems of the population by itself, but can improve customer choice by working to reformulate products. The final and key decision on what products a consumer will buy and consume is clearly always up to the consumer. Raising awareness about nutrition is therefore an integral and key part of the effort to improve the health of the population.

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If you are interested in this issue, check out the site **www.reformulace.cz** where information is published on reformulation and innovation in the food industry.

It also publishes this study.

The aim of the Platform for Reformulation is to create an expert forum to discuss the various reform objectives and technologies where the Platform members can:

- set and communicate specific commitments in the area reforming and promoting healthy nutrition;
- monitor and report results and share experiences with other manufacturers;
- educate the public in cooperation with the academic community and relevant ministries.

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