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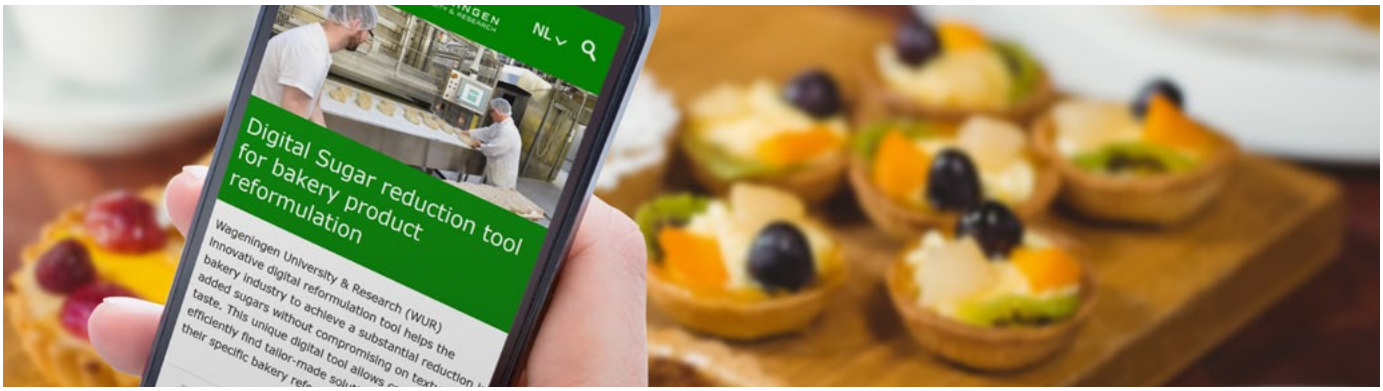


White Paper | WUR sugar reduction strategy

Thanks to digital tool based on the principles of physics

# WUR sugar reduction strategy is quick and successful

Sugar replacement in food products is challenging due to the different functions of sugar. Wageningen University & Research has developed a physics-based ‘‘sugar reduction strategy’’ and an associated digital tool to produce low-sugar recipes in an effective way. The tool has been successfully used in bakery products.

Rates of obesity, diabetes and cardiovascular diseases are on the rise and currently, sugar contribution to the daily energy intake is well beyond the recommendation by health organisations. Hence, food industry is urged to reduce the added sugar load of manufactured foods. As sugar performs a number of different functions in a food product it is difficult to replace.

Wageningen University & Research (WUR) has used a physics-based approach to come up with its ‘‘sugar reduction strategy’’ and has developed a digital tool to go with it. Using the digital tool, WUR experts can assist food product manufacturers to work out how to produce a low-sugar version of their existing products in a more efficient and time effective way, while still maintaining the original flavour and texture. The tool has already been successfully applied in the production of sugar-reduced biscuits, cakes and cookies.

CONTENTS

## The challenges of sugar reduction

Achieving a substantial reduction in added sugars without compromising on product quality is a real challenge. The most commonly used sugars are sucrose (also known as saccharose), glucose and fructose. These sugars deliver not just the required sweetness, but are also crucial for providing structure and mouthfeel (texture). They influence characteristics such as crispiness, softness and smoothness. That's why replacing sugar in a food product is a complex issue. It's not just about replacing the sweetener: you also need to find other ingredients that can replicate the structure and texture.

The trial & error approach, whereby some or all of the sugar is replaced with a single alternative sweet ingredient, often leads to a decreased end-product quality in terms of structure and mouthfeel, which is undesirable for consumers. On top of that, polyols – a group of commonly used sugar alternatives such as xylitol and maltitol – come with a further drawback. When used in high concentrations, they have a laxative effect.

## The WUR sugar reduction strategy

Wageningen University & Research has spent the past few years investing in a different approach to sugar reduction. "We've researched the functions of sugar from a physics-based perspective. So rather than looking at each individual ingredient, the way a product developer would do, we've been investigating the fundamental mechanisms underlying ingredient functionalities," say Ruud van der Sman and Stefano Renzetti, senior researchers in Food Physics and Applications. Their field of study – soft matter physics – has grown significantly over the past 20 years.

### *Soft matter physics research*

The extensive 'soft matter physics' research into the fundamentals of the various functions of sugar has led to a number of conclusions which have informed the WUR sugar reduction strategy. These conclusions are [2-6]:

- Sugar performs two physical functions in foods: it acts as a softening agent, and as a moisture absorber.
- These softening and absorbent properties can be provided either by sugar or by sugar substitutes.
- If sugar substitutes have the same softening and moisture-absorbing properties as sugar in the original product, there will be no change in the structure, texture and consumer acceptance of the product.
- Properties such as sweetness and browning can be independently controlled by adding small amounts of high-intensity sweeteners (such as stevia) or reducing sugars (such as fructose).

Wageningen University & Research is at the forefront of applying soft matter physics to food.

**Physics-based principles**

From a consumer perspective, mouthfeel and structure are important characteristics of food. Bakery products such as cakes and biscuits either need to be soft and fluffy, or crispy and crumbly. Dessert products such as ice cream and custard need a smooth mouthfeel.

These characteristics are determined by physical processes that take place during production. For example, cakes achieve their lightness when water held in the batter evaporates into steam, which at some point has to escape from the rising batter. This creates the soft, spongy structure that consumers want. But crisp bakery products, such as crackers, need to be porous and break easily with an audible snap. The principle is the same as with the soft bakery products, but more moisture is released and this creates the crisp product. To achieve a smooth ice cream, it's important that the ice crystals that form on the walls of the ice cream machine during the freezing process are small enough.

## *Roadmap for WUR sugar reduction strategy*

The application of the strategy can be done in a relatively short research project, which can involve the following steps:

The various **functions** of sugar in a food product are investigated and evaluated in how far they are characterised by the plasticising and humectant properties of sugar.

In consultation with the manufacturer, **a number of sugar replacing** ingredients are identified. In certain cases, the plasticising and humectant properties of novel alternatives to current sugar replacers can be assessed

The **possible combinations** of sugar replacers are calculated. The best sugar replacing mixtures for the specific application are identified and provided to the manufacturer.

**Practical testing** with various recipes determines the best formulation, possibly combined with sensory research into flavour and mouthfeel.

The physical processes that determine the structural development of foods actually depend to a large extent on the type and quantity of sugar used. So simply replacing sugar with a random sweetener is not an option.

**The theory of softening agents and moisture absorbers**

Adding milk to a crunchy cereal is an example of how softening agents work. Within moments of coming into contact with each other, the food has softened. A strong network of biopolymers provides crispiness in foods, and softening agents allow that network to break down by untangling the long molecules of proteins and polysaccharides such as starch. Water is the most commonly used softening agent. On a molecular level, sugar is similar to water and it too acts as a softening agent. Researchers at Wageningen have found that the softening properties of sugars are determined by the density of the hydrogen bonds that can be formed with other molecules[3,4,9,10,11].

Moisture-absorbing ingredients in food work by retaining water. Sugar is one such absorbent, as are proteins and polysaccharides. Any ingredient that absorbs water will in turn influence the freezing and boiling point of water. And freezing and boiling happen to be crucial processes in the transformation of a medley of ingredients into a food product.

The preparation of bakery products involves two temperature-dependent processes: the generation of steam, which creates lightness in the product, and the thickening of the biopolymer networks, which fixes the


airy structure that has been created. A higher sugar content will raise the boiling point of water, which in turn alters the steam formation and thus creates a different structure than you would find in a product with a lower sugar content [1,4,6,12].

The researchers found that the moisture-absorbent properties of sugar are determined by water activity. A reduction in sugar content calls for sugar substitutes that can provide the same water activity. A predictive theoretical model was built for this, based on the Flory-Huggins theory[2].

The WUR sugar reduction strategy has been used successfully in the production of reduced-sugar biscuits, cakes, cookies, sweets and other foods[1,6-7].

The application of the strategy has also revealed that it can be used for a variety of biopolymer networks:

- For biscuits, sugars control the aggregation of proteins while keeping the starch ungelatinised. That controls dimensions and textures of biscuits[6,13].
- For cakes, the starch pasting is controlled by sugars, while the sugars also affect protein network formation by the egg white proteins[1,7,9,12].

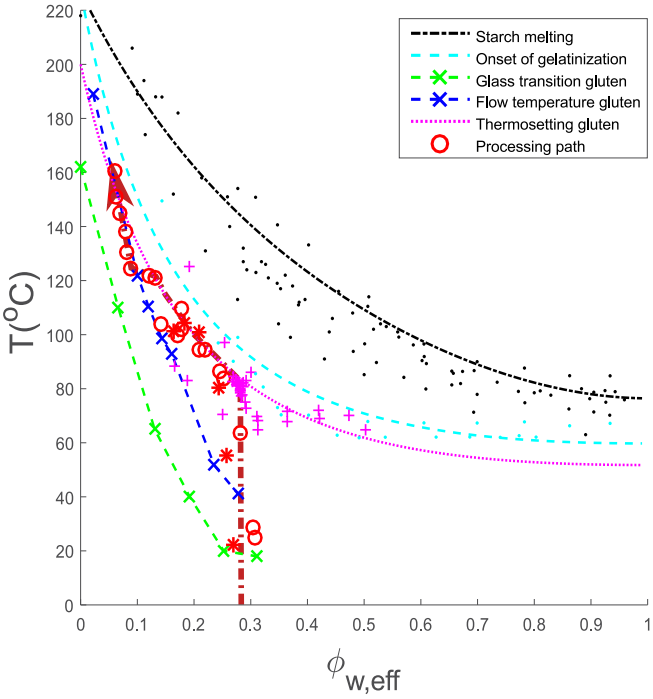


***figure 1*** Phase transitions during baking of biscuits as a function of the characterising number $\phi$w,eff. The glass transition, and stiffening of both gluten and starch are controlled by the same characterising number. The red circles show how the state of the food material changes during baking, showing that gluten stiffens, but that starch does not gelatinise. Other symbols indicate the stiffening of gluten as measured in biscuits with different sugar contents, and different sugar replacers as polyols. For more details see reference[6].

## The digital sugar reduction tool

WUR's digital tool for the sugar reduction strategy comprehensively integrates all current scientific understanding of the technical, nutritional, sensory and labelling requirements for bakery reformulations. Semantic technology and Artificial Intelligence support the decision-making process throughout the various reformulation steps, which means those steps can be performed more quickly and more accurately.

The tool has enabled Wageningen's researchers to achieve a 50-100% reduction in the use of sucrose in recipes for cookies and cakes, with no loss of texture and even managing to increase dietary fibre levels. The tool can also predict the effect of new sugar substitutes once their properties have been added to the database. It's been found that sweet amino acids, for example, could serve as sugar substitutes[12].

## The WUR sugar reduction strategy in practice

When food manufacturers approach Wageningen University & Research to reduce the sugar content of one of their products, the first step is to select the product type (cake, cookies or cereal bars) and to enter the existing recipe into the digital tool. Next, the reformulation objectives are determined. This includes the extent of

sugar content reduction, which sugar substitutes to use, and other criteria such as increasing dietary fibre, changing the calorie content and identifying the required sweetness level.

An important part of the tool is an extensive database that includes nutritional composition of the ingredients and physicochemical properties of the sugars and sugar replacers which are relevant for computing their functionality in recipes. It is also possible to characterise new ingredients and add it in the calculations. Based on that data and the selected criteria, the tool generates suitable alternative recipes. From the softening and moisture absorption properties that are calculated it is possible to select the formulations which best resemble the original product. The tool also calculates the Nutri-Score, using the latest algorithms (Santepubliquefrance). In consultation with the manufacturer, it is decided which formulations to produce and investigate further. Instrumental evaluation and sensory evaluation can be performed on the produced products to validate which formulation resembles the original products the best.

## Case studies of successful sugar reduction

### 1 Biscuits

Wageningen Food & Biobased Research worked with a biscuit manufacturer to compare the use of sugar and a variety of sugar substitutes (see figure 2). By using a mix of sugar substitutes – including fibres such as inulin – it was possible to match the softening and moisture-absorbing qualities of the original product ingredients and to reduce the sugar content by 50-100%. The reformulated biscuits met the manufacturer's quality standards, and taste tests found them to be similar to the original in terms of their appearance and mouthfeel[13].

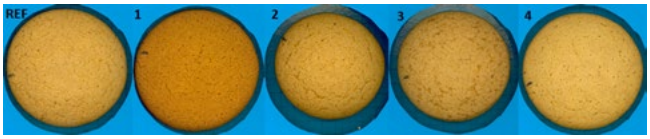


***figure 2*** Examples of reformulated biscuits. Biscuits 1-3 deviated from the reference (REF) biscuit with respect to the two characterising numbers, while biscuit 4 had about the same characterising numbers. Biscuit 4 mimics the reference biscuit well in terms of texture, mouthfeel and visual appearance.

### 2 Cakes

In cake production, both protein denaturation and starch gelatinisation are essential parts of the baking process, ensuring the formation of a firm but soft and light structure. Cakes with a lower sugar content can be of a comparable quality to the original recipe if the sugar substitutes have the same softening and moisture-absorbing properties as the original ingredients. This means that cakes baked using low-sugar recipes generated through the WUR sugar reduction strategy undergo the same protein denaturation and starch gelatinisation process as the original sugary cakes. The use of less suitable sugar substitutes alters the temperature of the starch gelatinisation process, resulting in an unacceptably poor quality cake [12] (figure 3).

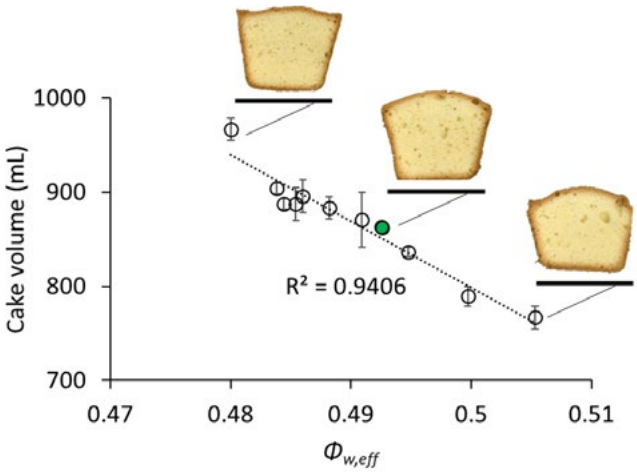


***figure 3*** Cake volume is predicted based on $\Phi_{w,eff}$. Green filled circle in indicates the reference sample.

### 3 Chocolate chip cookies

Can you make chocolate chip cookies with 25% less sugar while still retaining the same sweet taste and mouthfeel of the original cookies? Merba, a bakery in the town of Oosterhout (the Netherlands), wanted to find out. WUR researchers used their digital tool for sugar reduction to work out a recipe that immediately delivered cookies that almost matched the original product. The sensory panel was also impressed by the reformulated cookies.

**Packaging improves consumer acceptance of products containing less sugar**

Psychological strategies can influence the way consumers respond to products. For example, using the right colour packaging and providing the right sort of information can lead consumers to perceive a low-sugar product to be sweeter than it really is. Interested in this topic?

More details are available in the White Paper on Improving consumer acceptance of reduced-sugar foods.

# Frequently asked questions about sugar reduction

**What kind of products can the sugar reduction strategy and digital tool be used for?**
The WUR sugar reduction strategy is suitable for most food products that contain sugar. These include bakery products, sweets, breakfast cereals, desserts, ice cream, soups and sauces.

Food manufacturers can use the strategy to develop very specific low-sugar or sugar-free alternatives to their products, maintaining the same product structure and mouthfeel. In many cases it's possible to actually improve the nutritional quality of the products, for example by adding dietary fibre. The new recipes automatically comply with technological, quality and labelling requirements. Often, only a few practical tests will be needed. This considerably reduces the time-to-market for the low-sugar or sugar-free alternatives.

**How does the strategy help ingredient suppliers?**
The strategy provides ingredient suppliers with a better insight into the functionality of their sugar substitutes. This is particularly valuable when it comes to new sugar substitutes such as alternatives to polyols, which might include amino acids or fragmented dietary fibre from grains, fruits and vegetables. Armed with this knowledge, ingredient suppliers will be better able to advise their customers. The results of new Wageningen research, for example into the influence of hydrogen bonds on sweetness, may also lead to ideas for new sugar substitutes.

**Can the digital tool also provide a recipe for a product with a specific Nutri-Score?**
Absolutely. The digital tool contains all the information required for working out a recipe to meet a particular Nutri-Score. This would of course also take into account all other product qualities.

**What makes Wageningen Food & Biobased Research the right partner for this?**
Wageningen Food & Biobased Research has drawn on theories from the field of physics to develop the sugar reduction strategy, and has successfully applied it to a variety of bakery products. Our strategy is focussed on functionality (obtained from mixtures) instead of single ingredients. With a deep understanding of the behaviour of sugar and sugar substitutes in food products – and access to state-of-the-art laboratories – Wageningen experts can solve reformulation challenges for a wide range of products.

**More information?**

*Looking to reduce the sugar content in your products?*

Contact Joost Blankestijn for an informal discussion about the possibilities

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*More intrinsic information on the strategy?*

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