DLG Expert report 14/2018

Reduction Strategies for Fat, Sugar and Salt

Part 5 – Blueprinting as an instrument within recipe management

Reformulation

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The food industry is under continued pressure to reformulate products and this, coupled with ongoing recipe management, poses a significant challenge to technical and managerial staff. The majority of ingredients deliver important technical functions, and this along with raw material availability, regulatory requirements and economic factors all need to be taken into account. It requires complex formulation management which balances these factors without affecting the sensory qualities of the product. To this end, this expert report discusses the scientific approach of "blueprinting" as a helpful tool in food & beverage product development. It specifically addresses how product blueprints can help in meeting the challenges of salt, fat and sugar reduction strategies. Changes to ingredients, whether it be by type or concentration, can alter a product's blueprint in fundamental ways. Blueprinting helps developers understand and control the changes that occur when a product is modified during a reformulation project. To demonstrate how these changes can be analysed, addressed and managed, an example of building the blueprint of a biscuit using texture analysis, microscopy and sensory analysis is provided, along with a look at how this blueprint changes when sugar is subsequently reduced in the recipe.

Understanding the reformulation challenge

There are many reasons to reformulate a product, but every food business operator must sooner or later face a reformulation challenge. These can range from a simple change in resources when an ingredient becomes unavailable or unaffordable, to complex alterations of the recipe due to consumers' wishes and the need for innovation. The fast-paced, constantly changing environment that is the food and beverage industry requires creative thinking, quick responses and cost-effective processes to meet the demand for nutritious and tasty products.

Different trends continuously re-shape the market landscape. One of the most prevalent is the push towards healthy foods that are low in salt, fat and sugar. Yet, these reductions pose significant challenges due to the integral nature of these ingredients and the many functions they serve within a product. Changes to the product composition may affect technical processing properties, product quality and safety, shelf life, the sensory profile and, ultimately, consumer acceptance. This brings up the question of what to replace these ingredients with or how to change processing to counter-act detrimental side effects. In order to address these issues, the roles that salt, fat and sugar play in a recipe need to be understood, and this is one of the many ways blueprinting can help during product reformulation.

Addressing the salt challenge

Salt has numerous functions in foodstuffs. There are obvious sensory aspects such as creating saltiness and enhancing taste, but also flavour-modifying properties like suppressing bitterness and increasing sweetness. However, there is also a host of technological functions and effects to be considered: salt can be an important factor in determining shelf life due to its influence on water activity and its antimicrobial properties. This is particularly apparent in salt-rich foods like cured meat or salt-pickled vegetables.

Less obvious but arguably even more important are its technological roles in fields such as the bakery and meat industries. Bread dough with no salt will turn sticky, which makes it hard to process. Loaves and rolls without salt don't keep their shape very well and the crust remains a light colour, even after baking. In meat products, salt ions interact with proteins, influencing structure and texture of sausages and similar products. These effects are very hard to recreate with non-salt components and are crucial to overall product quality. Yet, there are ways to reduce salt in recipes.

On the one hand, in products where salt is used more for taste than for technological reasons, salt replacer ingredients can be helpful. These can be compounds where sodium, which is the driver for salt reductions due to its effect on the body, is substituted by other minerals such as potassium, or mixtures of substances or even herbs, spices and flavourings, which replace the lost saltiness with other interesting flavours to keep a product appealing. On the other hand, there are technological solutions. For dry salt applications, as the saltiness-sensation depends on the dissolution rate of salt crystals in the mouth, increasing the surface area to speed up this process can be an option. There are two ways to achieve this: The size of the salt component can be reduced, e.g. by producing micro- or nano-sized salt particles, or inert materials can be covered in a micro-layer of salt.

Another technological solution is to change the product structure. This can mean changes both of the micro- and macro-structure. One way to achieve an effect is by creating contrast in the product through layering of salt-rich and low-salt areas. This leads to a strong salty sensation even though the salt content in the product as a whole is lowered.

Reducing fat in products

There is a reason why fatty foods are so popular: fat not only has its own taste, it is also a major carrier for lipophilic flavour components and influences flavour in many ways. Like sugar, fat also plays a role in product colour and, in recipes with a significant amount, it is a contributor to volume. Especially important is the role of creating texture and mouthfeel. It communicates smooth, creamy texture and body. Through its influence on the behaviour of products in cold or warm conditions by modifying melting/freezing point, it makes treats like ice cream and chocolate even more enjoyable. Fat is also an important emulsion partner.

Replacing fat in a recipe is tricky. Though there are special fat-replacer ingredients available, like citrus fibre, these cannot completely recreate the mouthfeel and technological properties, and certainly not the taste. Another way to reduce fat is the use of emulsions, either as multi-emulsions e.g. water-in-oil-in-water (W/O/W) or emulsions with reduced droplet size, which leads to more droplets overall and a larger surface area available for ingredient interactions. Yet this may impede clean labelling or entail the use of multiple additives like emulsifiers and stabilisers, as well as flavourings.

Practical approaches to reducing sugar

Sugar, here meaning sucrose, has some similar properties and functions to salt. When thinking of sugar, sensory aspects are the first to spring to mind: sugar will produce sweetness, but it also suppresses sensations like bitter and sour. From a technological point of view, it is a versatile ingredient, e.g. influencing colour in bakery products where carbohydrates are responsible for browning reactions. In many foods, from cakes to candy, it is also a vital element in creating texture and mouthfeel. The properties of dissolving and reforming sugar crystals play a role in the smooth melt of fudge, crunchiness of biscuits or creaminess of ice cream. Microbiological cultures used in fermentation processes often require sugar as a substrate. Physical properties of sugar like the lowering of water activity influence shelf life and storage stability, as well as boiling or freezing points of liquids. Also, as a main ingredient, sugar can be a major contributor to product volume, which makes it difficult to omit.

The most straightforward answer to sugar reduction challenges is using sugar-replacers. These can be bulk sweeteners or intense sweeteners. In most cases, it is necessary to find a tailored blend of substances to fit the product, as many sweeteners possess a distinctive flavour which makes them unsuitable to be used on their own, and other technological properties need to be taken into account.

Sugar itself can also be modified to taste sweeter by reducing crystal size or modifying their structure, thereby reducing the necessity for large quantities. Furthermore, as with salt, the product structure can be altered to achieve an effect. Making use of sensory deceptions is another option: by adding colours and/or flavours, for example vanilla or fruit flavours, the sensation of sweetness can be elevated as the senses work in synergy.

Another fact to keep in mind is that sugar reduction is commonly associated with energy reduction by consumers. However, successful sugar reduction from a technological point of view does not necessarily go hand in hand with lowering energy content. Looking at the energy calculation of an example product (Table 1), where sugar has been reduced without adapting the rest of the recipe, illustrates that sugar reduction alone sometimes misses the mark, with the product ending up providing more energy rather than less.

Biscuit 1 (regular-sugar recipe)			Biscuit 2 (sugar-reduced)	
Weight (g)	Energy (kcal)	Component	Weight (g)	Energy (kcal)
100	900	**fat**	100	900
100	400	**sugar**	50	200
200	800	**flour**	200	800
400	2100	**total**	350	1900
	525	**Energy / 100g**		543

Table 1: Energy calculation for regular and reduced-sugar biscuits

Ultimately, to meet consumer expectations and create a successful, healthier product, consumer-oriented reformulation should always aim for an energy reduction as well, particularly when it comes to sugar and fat reductions. This usually means that the entire recipe will experience adjustments, with ingredients shifting proportions and new components coming in to moderate the technological impact of these reductions.

What is blueprinting and how can it help?

As demonstrated above, salt, fat and sugar influence a product in multiple ways and play various roles in a recipe. It is often difficult to keep track of all these aspects. This is where blueprinting can help to better understand a product and the purpose every single ingredient and process parameter fulfils within it, thereby putting control into the hands of the product developer.

The purpose of blueprinting is to, quite literally, provide a "blueprint" of the product and every single component in it, built from technical information obtained via scientific methods. Questions are answered, such as where exactly a component is physically situated and in what state it is. This is combined with information about product structure, texture and sensory data. In this way, the blueprint provides details about the origin of the product's properties, which allows for targeted manipulation and control of these pivotal points.

Goals of blueprinting

The wealth of data combined into a blueprint translates into several concrete goals: to create an objective product specification with which any modifications of the production process, ingredients etc. can be qualified, quantified and tracked; to understand the mechanisms underlying detectable sensory changes; and, ultimately, to build a scientific understanding of the product's behaviour.

In this way, blueprinting helps the R&D Team to work in a controlled, focussed fashion to achieve development goals quicker and with fewer costly detours.

In practice, the applications of a blueprint are endless. Whether it is the formulation of healthier products with a clean label, integration of new production technologies or the standardisation of process quality between manufacturing sites, blueprinting can help with anything from effectively using new ingredients and packaging to unravelling problems with production and legal conformity. Whatever the problem, the approach and the methods used are tailored by experts to supply the answers in a comprehensive picture that can be applied to any related case or similar problem that may occur in the future, thereby making a blueprint into a valuable investment.

"Ingredients" of a blueprint

A blueprint looks at different areas, such as ingredient functionality, texture, chemistry and structure (Figure 1) using various scientific methods. Important tools are light microscopy and scanning electron microscopy, rheological measurements and instrumental texture analysis. Sensory analysis is key in correlating physical measurements and observations with the actual consumer experience and product acceptability. For this purpose, both descriptive and affective methods are used.

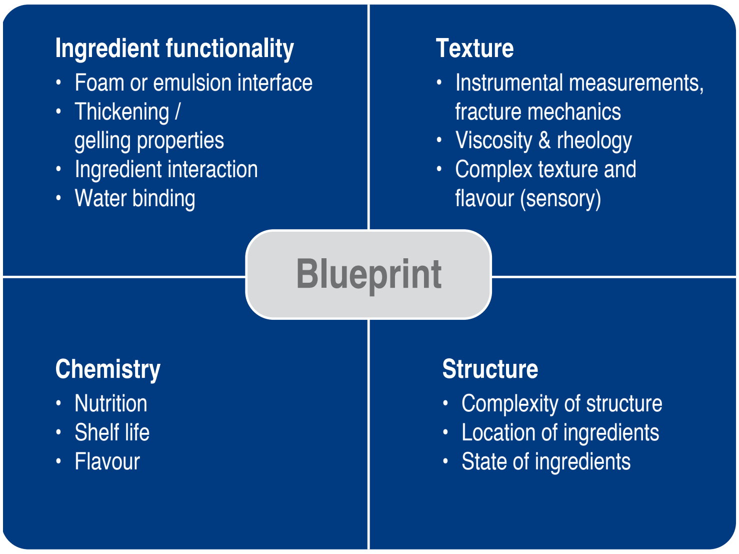

Figure 1: Ingredients of a blueprint

Each method delivers information on different areas of interest: microscopy, both light microscopy and scanning electron microscopy, is essential to explore microstructures and pinpoint where components are physically situated and how they are distributed throughout the product structure. For example, information on air distribution, how proteins and carbohydrates aggregate and interact or how fat behaves in different scenarios, e.g. when changing processing temperature, can be obtained.

This information can be combined with rheology and/or texture analysis measurements. With these methods, it is important to carefully evaluate if and how they can be applied. For instance, rheology can generally be used for liquid or semi-solid samples like creams and mayonnaises, whereas texture analysis is applicable for virtually any product, including gelled, firm and multi-component products like yogurts, cakes, fish fingers and pasta. The shape of the probe and the experimental set-up are key to obtaining valid, meaningful results. This is why it is important to consult experts on these methods before starting testing. Conversely, the more methods are applied, the more data will be obtained and a fuller picture can be assembled.

Finally, sensory testing is carried out on the product in order to link observations made in the laboratory to sensations experienced by the human senses. On the one hand, this can be descriptive testing, which is designed to identify and track certain parameters that can be correlated to physical measurements. For example, crunchiness of a biscuit can be associated with texture analysis data on maximum force for breaking the same biscuit. On the other hand, there are consumer tests where changes in parameters and perceptions are analysed to determine whether they have an effect on liking or preference, or even whether they are perceived by an untrained consumer at all.

Blueprints in practice

The possible applications of a blueprint are virtually endless. To demonstrate the basic steps of the blueprinting process, this section of the paper provides the practical example of a biscuit for which sugar content was reduced. For this demonstration, two biscuits were created: one with a basic recipe containing 18% sugar (biscuit 1) and one where the sugar has been replaced completely by a bulk sweetener (biscuit 2). As seen in Figure 2, the difference between both products is immediately obvious: biscuit 1 has a much darker colour and is also bigger in size. Now, building the blueprint will involve a thorough analysis of the biscuits to uncover the mechanisms behind these and other differences. Ultimately, by explaining the properties of the product, these will become controllable.

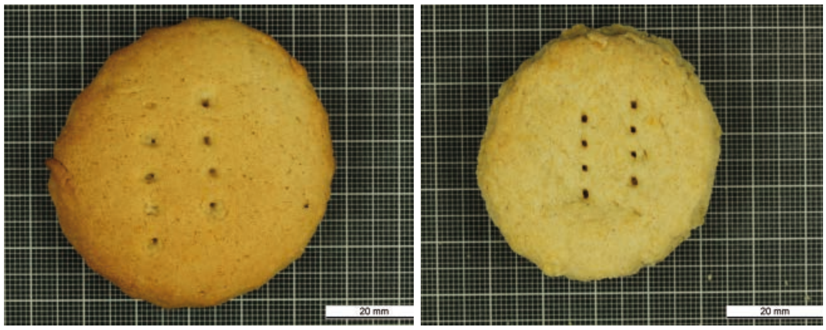

Figure 2: Biscuit with 18% sugar (left) and bulk sweetener (right)

Figure 3 provides a look at the crumb of both biscuits under a stereo-microscope at low magnification. Here, further differences become evident that give a first clue as to why biscuit 2 remains smaller: the air bubble structure is very different, but at this stage, it is not obvious why that may be the case. What can be seen, however, is that the air bubble structure also caused biscuit 2 to rise less as it is much thinner.

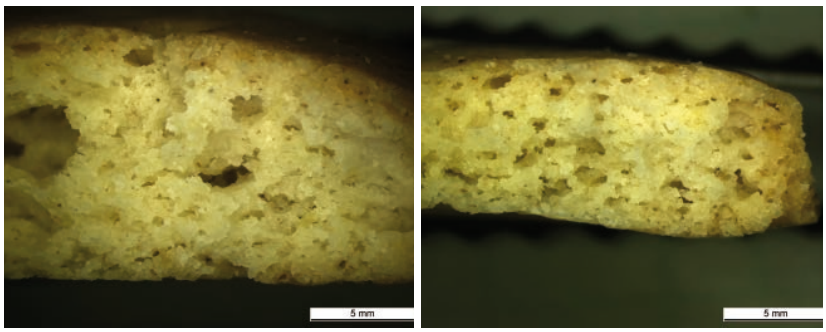

Figure 3: The crumb of biscuits 1 (left) and 2 (right)

With the help of stained slices of the biscuits' crumb viewed through a light microscope (Figure 4), even more information can be gathered as the blueprints for both product varieties begin to take shape: In this cross section, the difference in air bubble distribution becomes obvious: while biscuit 1 displays a light and foamy structure with lots of air inclusions (white areas), biscuit 2 presents with a dense structure with barely any air trapped in the crumb. The possible beginning of an explanation for this can be gathered from the visible differences in carbohydrate (purple) and protein (green) structure. In biscuit 1, the distribution of these is fairly even; while the starchy elements appear relatively cooked, the protein is dispersed uniformly around it. In contrast, in biscuit 2 the protein appears strongly aggregated with a very uneven distribution while the starch seems only partially cooked.

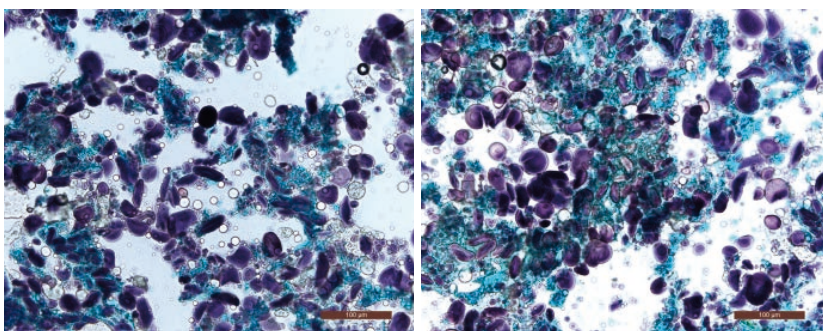

Figure 4: Stained slice of the crumbs of biscuit 1 (left) and biscuit 2 (right)

Additionally, a look through the scanning electron microscope (Figure 5) reveals both more details about the air distribution and the whereabouts of the fat component in the products. Curiously, the fat – appearing as lighter areas in the picture – seems to evenly coat the crumb of biscuit 1, while it is only partially distributed across the surface of biscuit 2.

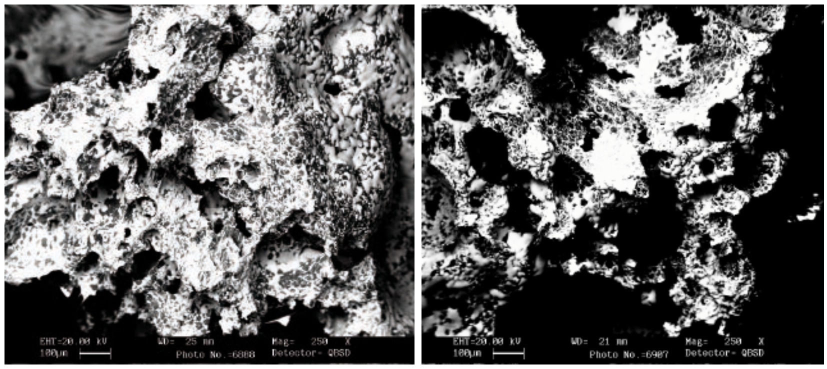

Figure 5: Scanning electron microscope image of biscuits 1 (left) and 2 (right)

By the visible structure of the crumb alone, it can already be suspected that the texture will be different. An instrumental texture analysis conducted on both biscuits confirmed that much less force is required to break biscuit 2 (Figure 6), which points to a softer crumb.

Finally, these findings need to be put into context through sensory analysis. A trained panel of descriptive sensory analysts determined that biscuit 1 had a darker colour, a firmer, more crunchy texture and a sweet, balanced flavour, whereas biscuit 2 was described as pale and uneven in colour, with a soft, mealy texture and a less sweet taste. This confirms that the differences observed in the laboratory lead to clear sensory discrepancies. For example, it can be theorised that the more compact structure would lead to a less crunchy crumb and that the starch, which was less cooked, may be responsible for the mealy or softer quality of the biscuit.

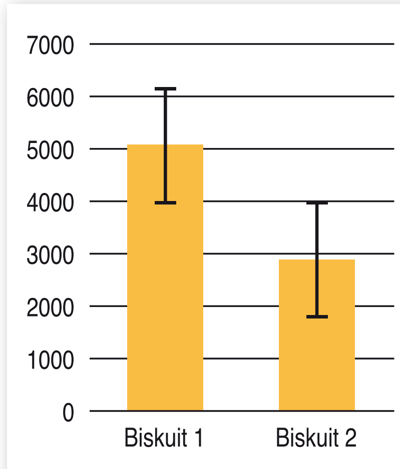

Figure 6: Force in grams necessary to break either biscuit

Results of the blueprinting

With the information gathered in the basic blueprint demonstrated above, it is now possible to devise starting points for addressing the uncovered issues. The solutions can range from adjustments to the recipe to modifications in the production process. One goal might be to improve aeration of the dough for biscuit 2, another may be adjusting the flavour and colour profile. It is up to the developer to determine, with the help of further sensory testing on consumers, which issues are the most pressing and relevant. In this way, blueprinting helps to not only provide information on possible causes, but also helps to prioritise solutions.

Conclusion

Product reformulations, for example reduction of salt, fat or sugar content, represent major challenges for food manufacturers, but blueprinting can help to overcome these challenges successfully. For this purpose, with the use of scientific methods, a blueprint is built with which the properties of a product and any changes to them can be objectively qualified and quantified. In this way, product development and innovation can be accomplished in a much faster and more goal-orientated way, putting manufacturers in a better position to conquer their market.

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