BAKINGEUROPE

Spring 2020

Flour improvers

How natural are they?

ALSO INSIDE:

Sustainability
Innovate to survive

Eggs
The natural multi-vitamin

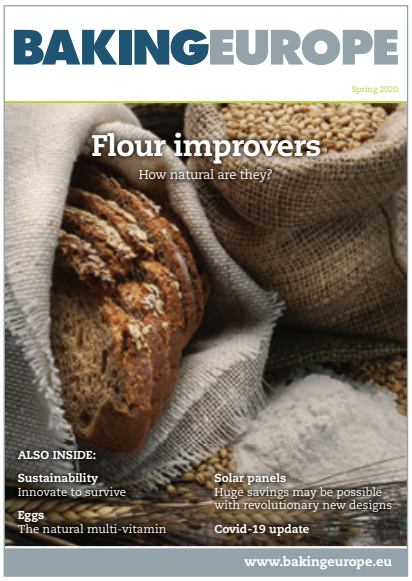
Solar panels
Huge savings may be possible with revolutionary new designs

Covid-19 update

www.bakingeurope.eu

CONTENTS

SPRING 2020



BAKINGEUROPE

EDITOR
Michael Edmund

DESIGN & PRODUCTION
Ray Heath

WEBSITE DESIGN
pulseart.co.uk

PRINTED BY
Printed in the UK

PUBLISHER
Graham Pendred

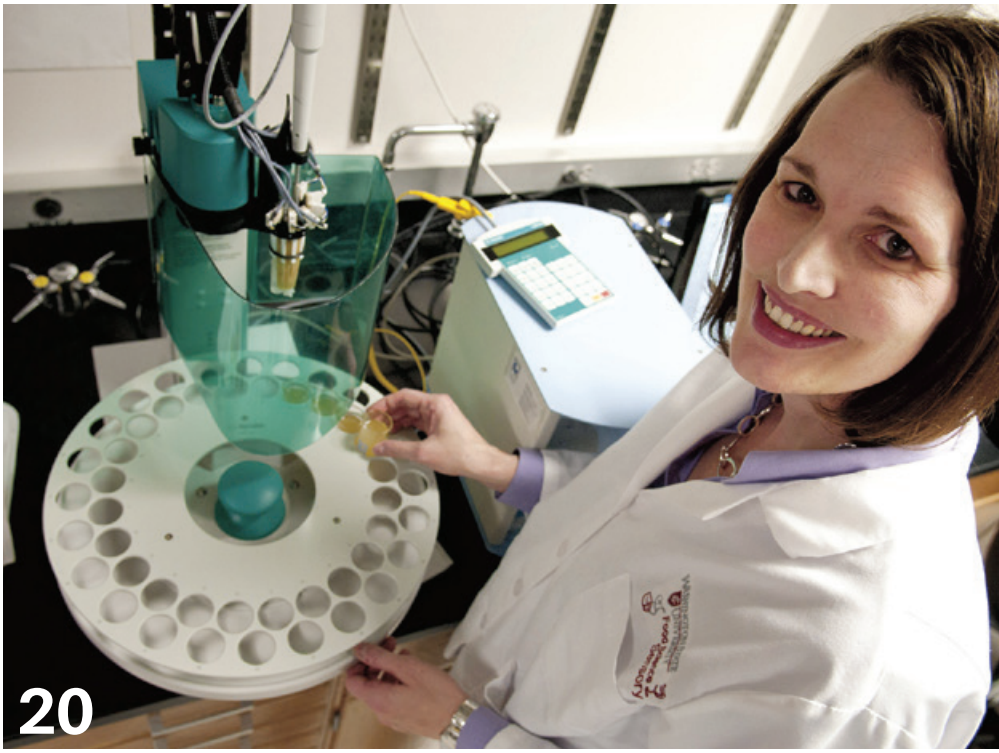
DIRECTOR

Trevor Brooker
trevor@bakingeurope.com

PROOF READER
Ann Richardson
Sarah Pendred

BAKINGEUROPE is published by:
Media Energy Ltd
Thorncroft Manor, Thorncroft Drive,
Leatherhead, Surrey KT22 8JB
United Kingdom

Tel: +44 (0)1372 365049
Email: enquiry@bakingeurope.eu
Web: www.bakingeurope.eu



Welcome

to the Spring 2020 issue of *Baking Europe*!

The early bumble bees have been chased away by encroaching shadows as the sun now begins to decline in the west, my garden's daffodils are once again in the shade and my tea is almost finished. During this time, sitting on the steps to my back door, I have been ruminating on the content our first Foreword of 2020, but after an hour of thought it seems clear to me that the scourge and ramifications of COVID-19, will be uppermost in all our minds.

We at *Baking Europe*, like us all, will never lose sight of the bigger picture, of those either infected or affected, whoever and wherever they may be. We all know, however, that to survive a crisis of this nature when entire countries are under lockdown, that food manufacturers and clockwork logistics, hold the key to keeping people fed and calm during their respective periods of isolation. These organisations have risen to the challenge are doing just that!

An afternoon trip to a food market just days ago saw me leaving empty-handed because there was nothing on the shelves. Today, I visited a large supermarket and was happily surprised to see all the shelves fully packed with food, including the enormous bakery section, which was carrying at least a 'baker's dozen' types of bread (pun intended!), plus a range of sensibly bagged confectionery.

The team here would like to extend our warm thanks and gratitude to everybody involved in the supply chain who has had to meet demand for, e.g.: ingredients, storage and transport, the bakers themselves and everyone involved, many working very long hours, to help bring their baked goods to our shelves and feed the nation. This is a scenario which will no doubt be playing itself out in your country. Thank you, and 'Chapeau!' to you all, you are marvels!

Now to the spring issue of *Baking Europe* and our usual collection of science, applied with, in places, a small helping of levity, e.g.:

Washington State University discusses how we can reduce the use of salt, whilst **Campden BRI** registers two pieces in this issue, one asking whether fridges are operating at the correct temperatures; and another questioning flour improvers and whether or not they are natural.

Klüber Lubrication's Anna Breuer is our interviewee in this issue, discussing the use of NSF H1 lubricants.

We are all affected by the sustainability *zeitgeist*, **Newcastle University** (AUS) examines exciting developments in solar panels to help reduce your costs. **Alix Partners**, discusses Private Equity funds and Venture Capital addressing the effects of market disruption created by increasingly health and environmentally conscious customers, and **FMCG Gurus** opine on the use of fashionable ingredients in baked goods, in Spain. Germany's venerable **TUM** (Technical university Munich) provides elucidatory research about the adhesion of dough... a sticky topic and the bane of many bakers!

Finally, we would like to acknowledge those who accepted commissions and who, due to forces majeure, have been unable to do so. We thank you also.

Trevor Brooker
Director

INVESTIGATIN

Are they nature's multivitamin?

By Carrie Ruxton PhD RD (pictured), Freelance dietitian

The British used to love consuming eggs until advice was given to curb consumption due to concerns about their cholesterol content[1]. However, this situation was reversed in the 1990s when the Lion Scheme was introduced successfully to control Salmonella[2] and the previous advice was overturned. This shifted the focus to more positive aspects of eggs such as their nutrient content and how they fit within a balanced diet. This article takes a look at the main nutrients within eggs and considers their potential impact on our overall health.

A GOLDMINE OF PROTEIN, ESSENTIAL AMINO ACIDS AND UNSATURATED FATS

While the high-quality protein content of eggs is well known, this isn't the case for the vitamins, minerals and fatty acids. Yet, eggs are a very rich source of specific nutrients, e.g. a portion of two eggs provides 100% of the European Nutrient Reference Value (NRV) for vitamin B12 and over 60% of the NRV for vitamin D (although in the UK this would be 32% as the recommendation was increased to 10 micrograms). In 2013, an updated nutrient composition for UK eggs was published by the UK Department of Health[3] providing new data for food tables. Since the 1980s, levels of energy, fat, saturated fat and cholesterol have reduced while protein has remained constant due to changes in the size of eggs as well as to poultry feeds[4]. An average medium-sized egg (58g raw) now provides 66kcal, 4.6g fat, 1.3g saturates and 177mg cholesterol (previous figures 78kcal, 5.8g, 1.7g and 202mg respectively).

A SOURCE OF VITAMINS, MINERALS AND A WHOLE LOT MORE

Table 1 presents data from this analysis. It can be seen that eggs qualify for several nutritional claims, including a 'source' of vitamin A, folate and phosphorus and a 'high/rich source' of vitamin D, riboflavin, vitamin B12, biotin, iodine and selenium. EU regulations define a source as at least 15% of the NRV while a high/rich source is at least 30% NRV[5]. Considering that there are few natural sources of vitamin D and eggs contain the more bioavailable form (D3), it is clear that eggs can make an important contribution to overall intake.

The data also show the modest energy and fat/saturated fat content of a portion of eggs (2 medium eggs) compared with

NG EGGS!

As one of the most complete natural foods available, eggs could indeed be viewed as nature's multivitamin.

EU Reference Intakes (RI). In contrast, the protein content of eggs is classed as 'high' and a portion would supply more than a quarter of the daily RI. Figure 1 breaks down the fat composition of eggs showing that most of the fatty acids are unsaturated, with the largest proportion from the monounsaturated group. When set against NRVs and RIs, a portion of eggs provides more than a fifth of the recommendation for choline, phosphorus and folate, and more than a third of the required riboflavin, biotin, iodine and selenium. The largest contribution is to vitamin D (64% NRV) and vitamin B12 (112% NRV). Thus, as one of the most complete natural foods available, eggs could indeed be viewed as nature's multivitamin.

SATIETY AND WEIGHT MANAGEMENT

During the past 14 years, nine randomised controlled trials (RCT) examined the potential impact of eggs on satiety and weight management (Table 2). The methodology of studies typically involves a test meal (breakfast or lunch) followed by visual analogue scales to estimate hunger, post-meal fullness (satiety) and desire to eat. Hormone levels are sometimes measured, e.g. ghrelin, a hunger-promoting hormone, and PYY, a satiety-promoting hormone.

In the acute studies (<4 days duration), changes to appetite hormones and hunger and fullness tended to be seen following egg consumption at a meal. However, energy intakes at a subsequent meal were not typically affected, except for the two studies which recruited normal weight men. In longer term studies, the differences in appetite control appeared to be impacting on energy intake as changes were noted to evening snacking in the Leidy *et al.* (2013) study while there were statistically significant benefits

Table 1: Nutritional composition of whole UK eggs (raw)

	Per 100g raw	Nutrition claims?	Per medium egg (58g) *	Portion as % Recs #
Energy (kcal)	131		66	7
Protein (g)	12.6		6.4	26
Total fat (g)	9		4.6	13
Saturated fat (g)	2.52		1.3	13
n3 PUFA (mg)	130		70	
Cholesterol (mg)	350		177	
Salt (g)	0.38		0.2	7
Vitamin A (µg)	126	Source	64	16
Vitamin D (µg)	3.15	High	1.6	64
Vitamin E (mg)	1.29		0.7	12
Vitamin K2 (µg)	7		3.5	9
Thiamin (mg)	0.08		0.04	7
Riboflavin (mg)	0.5	High	0.25	36
Niacin (mg)	0.05		0.03	0.4
Vitamin B6 (mg)	0.13		0.07	10
Vitamin B12 (µg)	2.7	High	1.4	112
Folate (µg)	47	Source	24	24
Biotin (µg)	19.5	High	9.9	40
Choline (mg)	285		144	72
Phosphorus (mg)	179	Source	91	26
Calcium (mg)	46		23	6
Potassium (mg)	145		73	7
Iron (mg)	1.72		0.9	13
Zinc (mg)	1.12		0.6	12
Iodine (µg)	50	High	25	33
Selenium (µg)	23	High	12	44

Key:* weight includes shell but analysis reflects edible part only; # a portion refers to two 58g eggs (edible part only); % Recs = percentage of Reference Intakes for macronutrients and Nutrient Reference Values for micronutrients[6] except for choline for which an Adequate Intake of 400 mg was set by EFSA in 2016[7].

Figure 1: Fatty acid composition of eggs

to body weight and body fat loss in the large intervention by Vander Wal *et al.* (2008). In Bayham *et al.* (2014), a similar pattern was seen in the acute studies where differences in hormone levels and perceived fullness did not translate into energy reduction. This may be because food consumption is largely driven by habit and volume.

It is clear in these studies that consumption of eggs – a high protein food with the complete range of amino acids – is consistently influencing hunger and satiety as well as appetite hormones. In the Marsset-Baglieri *et al.* (2015) study, it was interesting to note the delay in protein absorption and utilisation following egg consumption compared with the similarly high protein cottage cheese. This suggests that the balance of amino acids in egg protein may be metabolised more slowly and, hence, produce a different profile of hormones. More research is needed to establish why some people eat less when given an egg breakfast or lunch and what might be the ideal intake of eggs for promoting satiety. In the meantime, eggs appear to be a beneficial component of weight management diets.

More research is needed to establish w people eat less when given an egg brea lunch and what might be the ideal inta for promoting satiety.

EVIDENCE OF HEALTH BENEFITS

Whilst research on eggs is amassing across many disparate areas, studies are still skewed towards observational types – basically large uncontrolled surveys – whose findings are clouded by subjects traditionally eating less healthy foods with eggs, such as bacon or fried foods. Such studies have reported statistical associations between high egg consumption and the risk of cardiovascular disease in people with type 2 diabetes [8,9]. However, this has been challenged by two RCT which examined the impact of a high egg diet on lipid profiles in people with type 2 diabetes. In the first[10], 140 people with type 2 diabetes were randomised to consume a high egg (>12/week) or a low egg (<2/week) diet for 3 months. No differences were found in lipid profile or glycaemic control at the end of the intervention. Interestingly, people in the high egg group reported less hunger and greater satiety post-breakfast. In the second trial[11], 65 participants with type 2 diabetes or impaired glucose tolerance consumed 14 eggs/week or 100g lean animal protein for 12 weeks. While both groups showed improved glycaemic and lipid profiles, blood pressure and apo-B, results were better for the high egg diet. In contrast to epidemiological research, these studies suggest that eggs have a positive impact on health in people with type 2 diabetes.

Regular readers of *Baking Europe* will be aware of the various studies that we have published on the diets of older people and it is this population group that has been the focus on several new studies looking at the benefit of eggs. In one observational study[12] of 2497 dementia-free middle-aged men, egg intake was statistically associated with better performance on neuropsychological tests of the frontal lobe and executive functioning. The mechanism may relate to choline and, indeed, this was an ingredient in a medical nutrition product which slowed cognitive decline in patients with early stage Alzheimer's[13]. Choline is also used in drugs for treating cognitive disturbances in the elderly.

Sarcopenia (muscle loss) is

a common disorder in older people leading to falls and loss of mobility. Evidence suggests that a high protein diet – particularly one containing high biological value protein – can stem the decline in muscle tissue. According to a recent review, eggs can play an important role in boosting the protein content and nutritional value of older people's diets. Vitamin D is also an important nutrient for preventing falls, as acknowledged by a European health claim, and this is a major nutrient found in eggs.

CONCLUSIONS

Eggs are a high protein, low fat nutritious food that could be considered as 'nature's multivitamin', particularly as they are one of the few natural sources of vitamin D. In contrast to earlier fears, now disproved, that the cholesterol content could adversely affect health, regular consumption of eggs appears to promote satiety which may lead to better weight control. Eggs are also a useful protein source for people with type 2 diabetes. Further research on cognitive function, sarcopenia and glycaemic control is warranted but in the main, this all represents good news for the world's bakers.

ACKNOWLEDGEMENT

This article was based on research funded by the British Egg Industry Council. For more information, see www.egginfo.co.uk ■

FOR MORE INFORMATION

Dr Carrie Ruxton
www.nutrition-communications.com
carrie@nutrition-communications.com
+44 7973-337757

REFERENCES

1 Gray J & Griffin B (2009) Eggs and dietary cholesterol - dispelling the myth. Nutr Bull 34: 66-70

2 www.egginfo.co.uk/british-lion-eggs

3 Department of Health (2013) Nutrient analysis of eggs www.gov.uk/government/uploads/system/uploads/attachment_data/file/167973/Nutrient_analysis_of_eggs_Analytical_Report.pdf

4 Benelam B. et al. (2012) New data on the nutritional composition of UK hens' eggs Nutr Bull 37: 344-349

5 Buttriss J (2013) Food labelling: Changes associated with introduction of new legislation. Nutr Bull 38:383-388

6 European Commission (2008) COMMISSION DIRECTIVE 2008/100/EC od 28 October 2008 amending Control Directive 90/496/EEC on nutrition labelling for foodstuffs as regards recommended daily daily allowances, energy conversion factors and definitions.

7 European Food Safety Authority (2016) www.efsa.europa.eu/en/press/news/160817

8 Pearce KL et al. (2011) Egg consumption as part of an energy-restricted high protein diet improves blood lipid and blood glucose profiles in individuals with type 2 diabetes. Br J Nutr 105: 584-92

9 Ylilauri MP et al. (2017) Association of dietary cholesterol and egg intakes with the risk of incident dimentia or Alzheimer's disease: The Kuopio Ischaemic Heart Disease Risk Factor Study. Am J CliNutr 105: 476-484

10 Ritchie CW et al. (2014) Souvenaid®: a new approach to management of early Alzheimer›s disease. J Nutr Health Aging 18: 291-9.

11 Smith A & Gray J (2016) Considering the benefits of egg consumption for older people at risk of sarcopenia. Br J Community Nurs 21: 305-9.

12 Ylilauri MP et al. (2017) Association of dietary cholesterol and egg intakes with the risk of incident dimentia or Alzheimer's disease: The Kuopio Ischaemic Heart Disease Risk Factor Study. Am J CliNutr 105: 476-484

13 Ritchie CW et al. (2014) Souvenaid®: a new approach to management of early Alzheimer›s disease. J Nutr Health Aging 18: 291-9.

New reference: Missimer A et al. (2017) Consuming Two Eggs per Day, as Compared to an Oatmeal Breakfast, Decreases Plasma Ghrelin while Maintaining the LDL/HDL Ratio. Nutrients 9(2). pii: E89.

FLOUR IMPROV

Can they be natural?

By Dr Gary Tucker, Technical Development Ambassador, Campden BRI

VERS

For thousands of years, bread has been baked using a mixture of different cereal flours and water. Wheat has remained as the main cereal because of its unique blend of proteins that combine during mixing to form the desired gluten network. These create a dough with both viscous and elastic properties to help retain the gases given off during fermentation and proving. Without gluten, dough loses gas and does not lighten in texture during proving, resulting in baked bread which is dense and hard. More recently, bread manufacture has evolved to use a variety of added ingredients of benefit to processing and the final product. This article discusses the use of these minor, but highly functional ingredients in modern plant baking and whether it is possible for these to emanate from a natural or clean label source.

Bread composition has changed little over the years, while bread making techniques have evolved considerably during the same period. Historically, bread was made using a 'sponge or brew' system in which flour was mixed with water, and sometimes yeast. The 'sponge' or 'brew' was then left to ferment for a period of several hours or even days. Considerable beneficial changes to the functionality of wheat flour happened during this period, driven largely by the action of enzymes. After fermentation, other ingredients and additional flour were added and the dough remixed. Simple ingredients such as salt, vinegar and sugar were added to help preserve the finished baked product. Following a time of rest, the dough was divided into pieces, placed in pans, allowed to rise and then baked.

Most of the bread consumed in Europe is now produced by large plant bakeries manufacturing bread and other baked goods on an industrial scale. Machinery, technology and science are put to full use in automated bread making processes designed to deliver consumers what they want – quality, consistency, convenience and price. There will always be debates about industrial bread being different from traditional bread, but the fact remains that around 80% of bread consumed today is plant produced bread. Access to local bakeries enabling fresh bread to be bought daily has diminished as our western lifestyles have changed. Consumers seem to prefer soft bread that lasts at least five days before going mouldy or stale.

There are a number of ways that plant bakeries achieve a lengthy shelf-life using both processing and ingredient solutions. Processing solutions focus on optimising the dough mixing processes so that better use is made of the gluten-forming proteins. The inclusion of air bubbles of various sizes also defines the texture of the bread and gives it its characteristics features. This article covers the ingredient solutions, referred to as improvers, that can be used by bakeries to improve the quality of bread products.

INGREDIENT SOLUTIONS

Bread formulations started life as flour, water, yeast and salt – all of which are natural ingredients – but as bread production became more automated and consumers demanded softness and longer shelf-life, the ingredients list increased in size. Table 1 shows the differences between historic bread recipes and those currently used commercially for a standard white loaf.

This is where 'improvers' come in. But what is an improver? Fats/oils, emulsifiers, oxidising or reducing agents, enzymes and preservatives are examples. They are highly functional ingredients which are added to the dough or bread in small quantities i.e. at dosing rates between 20ppm and 3% (on flour weight). Table 2 outlines the approximate dosing levels of these ingredients, again in white bread, and refers to their specific functional attributes. It is common to add these as a blend, known as an improver or concentrate, because this helps with weighing accuracy.

Table 1: Recipe for standard white bread, shown in Bakers %

Ingredient	Historic recipe	Commercial recipe
Flour	100	100
Water	55-60	60-65
Yeast (block)	1.5-2.0	2.0-2.5
Salt	2.0-2.5	1.3-1.5
Fat / oil	-	0.5-2.0
Commercial Improver (powder or oil-based)	-	0.5-2.0

Table 2: Dosing levels of minor ingredients added to white bread, shown in Bakers %

Ingredient	Category	Function	E number	Dosing level
Soya flour	-	Carrier for the improver, but also crumb whitener and softener	-	0.5-1.5%
Vegetable oil	Fat / oil	Crumb softener	-	0.5-2.0%
DATEM (diacetyl tartaric acid esters of mono- and diglycerides)	Emulsifier	Bubble stabilisation	472e	0.3-0.5%
SSL (sodium stearoyl lactate)	Emulsifier	Some bubble stabilisation and keeps crumb soft over shelf-life	481	0.3-0.5%
GMS (glycerol monostearate)	Emulsifier	Keeps crumb soft over shelf-life	471	0.3-0.5%
Ascorbic acid	Oxidising agent	Gluten development	300	60-100ppm
L-cysteine	Reducing agent	Dough extensibility	920	20-40ppm
Amylases	Enzyme	Sugar generation for yeast activity, delays staling	-	10-100ppm
Xylanases	Enzyme	Fibre breakdown making dough softer	-	20-40ppm
Calcium propionate	Preservative	Mould inhibitor	282	1,000-2,000ppm

FATS, OILS AND EMULSIFIERS

Hard, saturated fats are known to be better than oils for stabilising bread and cake crumb over the shelf-life of a product. However, they are being replaced by mono- and polyunsaturated oils for health drivers and their ease of use in the bakery. The downside of using liquid fat is that it requires an increase in emulsifier level or additional ingredients to boost the lost functionality we have just alluded to.

Tropical oils, such as palm, have a high melting point that maintains the fat in solid form for longer, which is ideal for stabilising gas bubbles in dough more effectively than oil. However, the use of palm oil is increasingly controversial due to sustainability and environmental concerns. There is pressure to reduce its use or replace it with locally sourced oils such as sunflower or rapeseed oil.

The downside of using liquid fat is that it requires an increase in emulsifier level or additional ingredients to boost the lost functionality.

Emulsifiers have also developed over the past 40 years. Their role is to bind to key flour components such as protein, starch and fat. This helps to stabilise the liquid films that surround gas bubbles in dough so that more of the bubbles remain intact during dough processing and into baking. Bread with a fine network of gas bubbles will be softer and appear whiter than with coarse bubbles. Some emulsifiers are specifically used to maintain softness throughout shelf-life, such as glycerol monostearate.

The three main emulsifiers used in the bread industry are DATEM, SSL and GMS. Natural emulsifiers such as lecithin are used to a limited extent because they are less functional and less consistent than their manufactured alternatives. Cake making uses lecithin found naturally in egg. Other natural sources include soya, albeit an allergen, and in sunflower and rapeseed.

OXIDISING AGENTS

Another group of bread improvers is that of oxidising agents, such as ascorbic acid (otherwise known as vitamin C). This is a naturally occurring organic compound with antioxidant properties. When flour is mixed with water, the gluten swells to form a continuous network of fine strands and it is this network

Dried fruit extracts, for example from p acerola cherry, can be used as alternat ascorbic acid.

which forms the structure of bread dough, making it elastic and extensible. It is necessary for oxygen to be present, combined with action from an enzyme naturally present in flour, to convert ascorbic acid from its natural reducing form to the active oxidising form. Oxidising agents improve the gas retention abilities of dough by cross-linking the gluten network. The overall result is that the gluten develops more effectively producing a less dense, higher volume bread with improved crumb softness.

Natural oxidising agents are readily found in fruits and vegetables. Our work at Campden BRI has shown that dried fruit extracts, for example from plum and acerola cherry, can be used as alternatives to ascorbic acid. As with many natural solutions they are less consistent in their oxidising activity. There were also some colouration issues with certain extracts which caused the bread crumb to turn grey or purple. It is possible to remove the colour forming compounds but this requires a further processing step that moves the ingredient away from being natural.

Another category of natural oxidising agents is oxidising enzymes. These are considered later in the section on enzymes.

PRESERVATIVES

Preservatives are used in bread making to prevent the growth of microorganisms that would cause the bread to spoil too quickly. Most chemical preservatives used in baking increase in effectiveness as the product pH is lowered. This is because more of the organic carboxylic acids, which are the active components of the preservative, work at lower pH levels.

Common preservatives include acetic acid, propionic acid, sorbic acid and lactic acid. Calcium propionate is commonly added in breads and other baked goods because of its ability to inhibit a broad spectrum of moulds and other microorganisms. It is not toxic to these organisms but prevents them from reproducing and spoiling the products. Other commonly used preservatives in the baking industry include sodium propionate and potassium sorbate which all help preserve breads and baked goods. Without them, mould would quickly start growing within three or four days. The active form of these preservatives is the acid but they are added as salts for ease of handling and higher solubility.

Natural alternatives to chemical preservatives have existed in bread making since the first bread was made using a starter culture. Microorganisms naturally present in flour grow within the starter culture and generate a host of compounds that have benefits in bread making. These benefits range from improved gluten development, flavour enhancement, dough softening, increased yeast activity, preservation, and even dietary benefits are claimed. The preservation action is through the generation of carboxylic acids, such as propionic, lactic and acetic, from specific bacteria. Sour dough bread lasts longer because of the organic acids generated in the starter and during the lengthy fermentation steps. Dried cultures of the bacteria from sour dough can be purchased from ingredient companies to shortcut the process and to ensure the acidic flavour and texture of the bread does not change over time.

ENZYMES

One of the ingredient groups that now finds its way into almost all types of bread is enzymes. Without enzymes, bread as we

know it today would be different. Enzymes help speed up the chemical reactions required in dough processing and during the early parts of baking. Just small amounts of enzymes, at parts per million levels, are required. Enzymes are available to complement or replace most components of the improvers. Some of these enzymes can be introduced using natural ingredients, such as malt flour or soya flour, which are rich in specific enzymes.

Probably the first enzymes to be used in bread making were alpha amylases. These act on starches and convert them to sugar materials. When dough is made, the yeast starts to transform fermentable sugars into alcohol and carbon dioxide, making the dough rise. At the start of the process, fermentation uses the small amount of fermentable sugar in the flour. When this is used up, fermentation will stop unless new supplies of sugar are made available to the yeast. Amylase is naturally present in flour, but if its levels are low this leads to low sugar levels and poor gas production. This in turn leads to an inferior quality of bread with reduced loaf volume and a pale crust. This is where adding such an enzyme can help. Conversely if the amylase levels are high this can cause too much sugar production at a time when yeast activity has ended, and this can result in sticky crumb that is difficult to slice. Malt flour is rich in amylases and can offer a similar function to fungal amylases.

The next most common group of enzymes is used to prevent staling. A loaf of bread starts to go stale soon after it leaves the oven, and a progressive staling process occurs, characterised by starch crystallisation and hardening of the crumb. The addition of a different type of amylase helps change the structure of the starch so that it cannot recrystallise as easily. This group of amylases has attracted considerable attention from enzyme manufacturers. Each generation of amylases is more effective than the previous. Breads produced with these amylases have a softer and more elastic crumb than breads that do not have them added. Without them, bread stales after 2-3 days. There is no natural enzyme solution to retaining the crumb softness for longer. Higher levels of fat or oil, and increased sugar will perform a similar function, but neither are ideal for health reasons.

Also high on the diet and health agenda is the inclusion of fibre into baked goods. Fibre materials are beneficial to our health and efforts are made to include them into bakery products. However, fibres such as wheat bran absorb a lot of water and more slowly than other components in dough. This causes processing issues with tight dough that does not mould well but also resists expansion by yeast action resulting in poor quality bread. An enzymic solution with xylanases is available and is now used in most industrial bread manufacture. Xylanases cut some of the linkages of large fibre molecules to release low molecular weight sugars and water. This helps soften dough so it can be processed with fewer issues. Commercial xylanases are generated from bacteria and fungi. Natural sources exist widely in nature but not in sufficiently pure forms that work consistently well in bakery products.

There are several other enzymes used in bakery products that confer specific benefits. Glucose

Table 3: Common enzymes used with bakery products

Enzyme category	Function
Fungal *alpha* amylase	Sugar generation for yeast activity
Maltogenic *alpha* amylase	Delays the staling process
Xylanase	Fibre breakdown making dough softer and processable
Lipase	Generation of natural emulsification materials
Glucose oxidases	Dough oxidation / development
Lipoxygenase	Dough oxidation / development and crumb whitening
Proteases	Breaks gluten network, allowing dough to flow

As enzymes are destroyed by the high temperatures involved in the baking process, bakers can achieve a highly desirable clean label image for their product.

oxidases and lipoxygenases both help with gluten development, and lipoxygenase also makes bread crumb whiter. Proteases soften dough, making it flow better, which is useful when the dough must fill a mould or flatten out as with pizza bases. However, it is the amylases, lipases and xylanases that find the greatest use in bakery product manufacture. Table 3 summarises the common enzymes used in baking.

One advantage of enzymes is that they do not require labeling because they are inactivated during baking and are not active in the baked bread. Looking to the near future, however, there are significant changes ahead in terms of the use of enzymes in food due to the changing legislative landscape. For the first time, there may be specific EU legislation on the use of enzymes in food. The EU is in the process of compiling a long list of permitted enzymes that can be placed on the market and used in food. While it remains to be seen what the outcome of European Union Regulation 1332/2008 will be, it is safe to say that it will have far-reaching implications for the baking industry.

Regardless of changing regulatory requirements, enzymes as processing aids in the baking industry are here to stay. Their functional capabilities, clean label properties, ability to create more efficient processes and to reduce costs mean they are an essential ingredient in bakery products. The huge advantage of using enzymes is that many occur naturally in bakery ingredients such as wheat and soya flour. Furthermore, as enzymes are destroyed by the high temperatures involved in the baking process, bakers can achieve a highly desirable clean label image for their product.

"CLEANING UP" LABELS

Natural ingredients are now desired by consumers as the drive for clean label continues. The E-number concept was introduced to assure consumers that an ingredient was safe for use in foods. However, the very presence of an E-number is now viewed negatively and bakeries take efforts to minimise their inclusion. Consequently, bakers are looking to replace 'additives' and E numbers with ingredients that are perceived to be less processed and more 'natural'.

The importance of enzymes is only going to increase as consumers demand more natural products free of 'chemical' additives. As consumers continue to demand consistently high quality, tasty, attractive baked goods with longer shelf-lives, enzymes will maintain a key role in the bakery process. One of the challenges for bakers is to find and develop natural sources of enzymes. This is a research area that offers potential. ■

FOR MORE INFORMATION

Campden BRI
food and drink innovation

Dr Gary Tucker, Technical Development Ambassador, Campden BRI
gary.tucker@campdenbri.co.uk,
www.campdenbri.co.uk

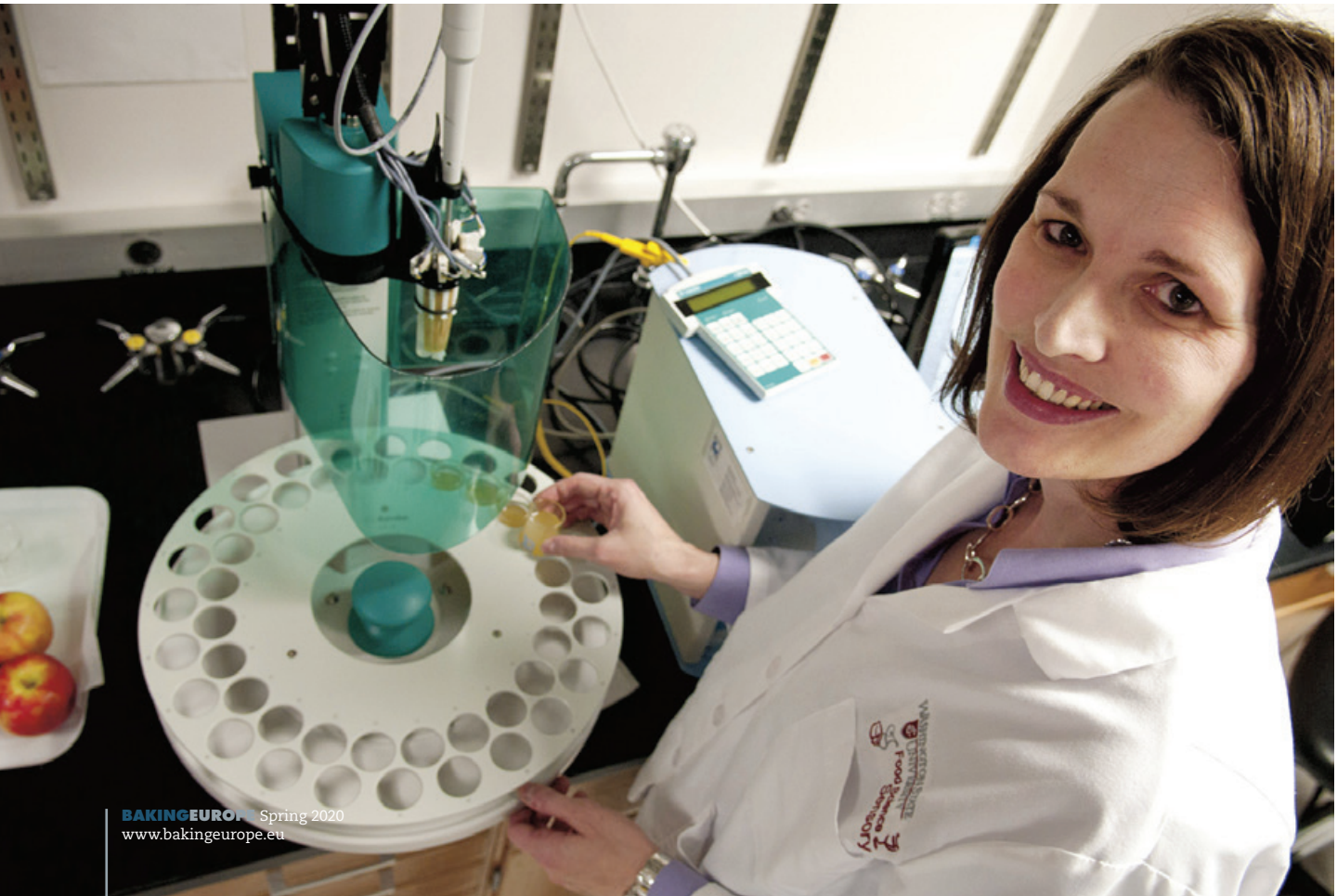
An (electronic) tongue perception of 'salty'

By Carolyn F. Ross (pictured), Professor, School of Food Science, Washington State University Pullman WA 99164-6376

How we can reduce salt and provide accurate evaluations using people and instruments

Reducing the amount of salt in foods, especially processed foods, has become an area of great interest in the food industry. The negative impacts of the over consumption of salt has led to many health concerns including increased blood pressure, risk of cardiovascular disease, stroke and renal disease. To help address these health concerns, the World Health Organisation has set a salt reduction target of 30% by the year 2025 (WHO, 2012).

Salt contributes significantly to our enjoyment of food and when most people think about salt, of course, they think about taste and flavour. However, salt goes beyond just providing a 'salty' taste to a food, since it is a multifunctional component in food. Salt is important in reducing water activity, inhibiting the growth of some microorganisms, and thus allowing for greater microbiological safety (think of pickles for example.) Salt also affects food product texture by interacting with other major components in foods.



While $CaCl_2$ and KCl provide a salty perception, they also provide other unwanted sensory changes.

For example, salt increases the hydration of protein and enhances binding of proteins to each other and also to fat; this is useful in the development of a network of gluten proteins in yeast breads. From a sensory standpoint, salt not only elicits the perception of saltiness but also influences overall flavour perception and masks off-flavours.

Considering all the contributions salt makes to food, its removal is not an easy task. Reducing salt content without a loss of consumer acceptability has become a major challenge to food manufacturers. Food scientists have identified several salt

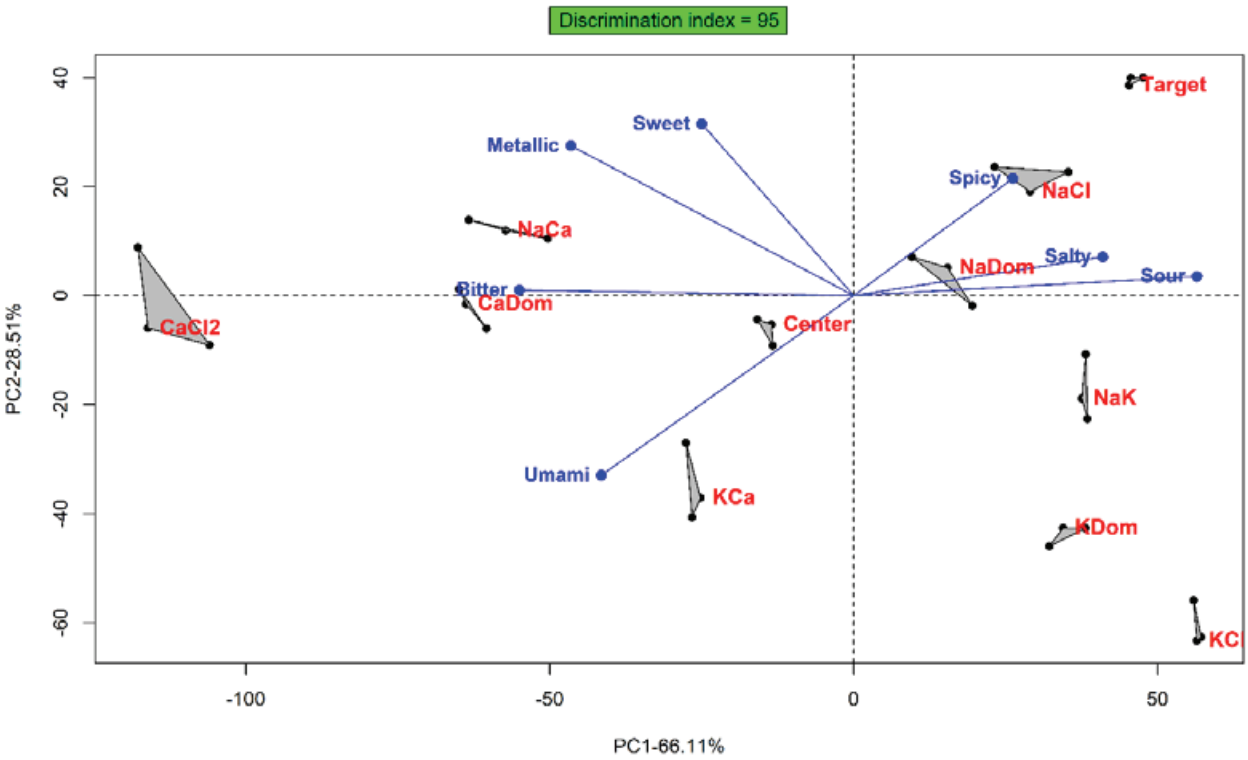
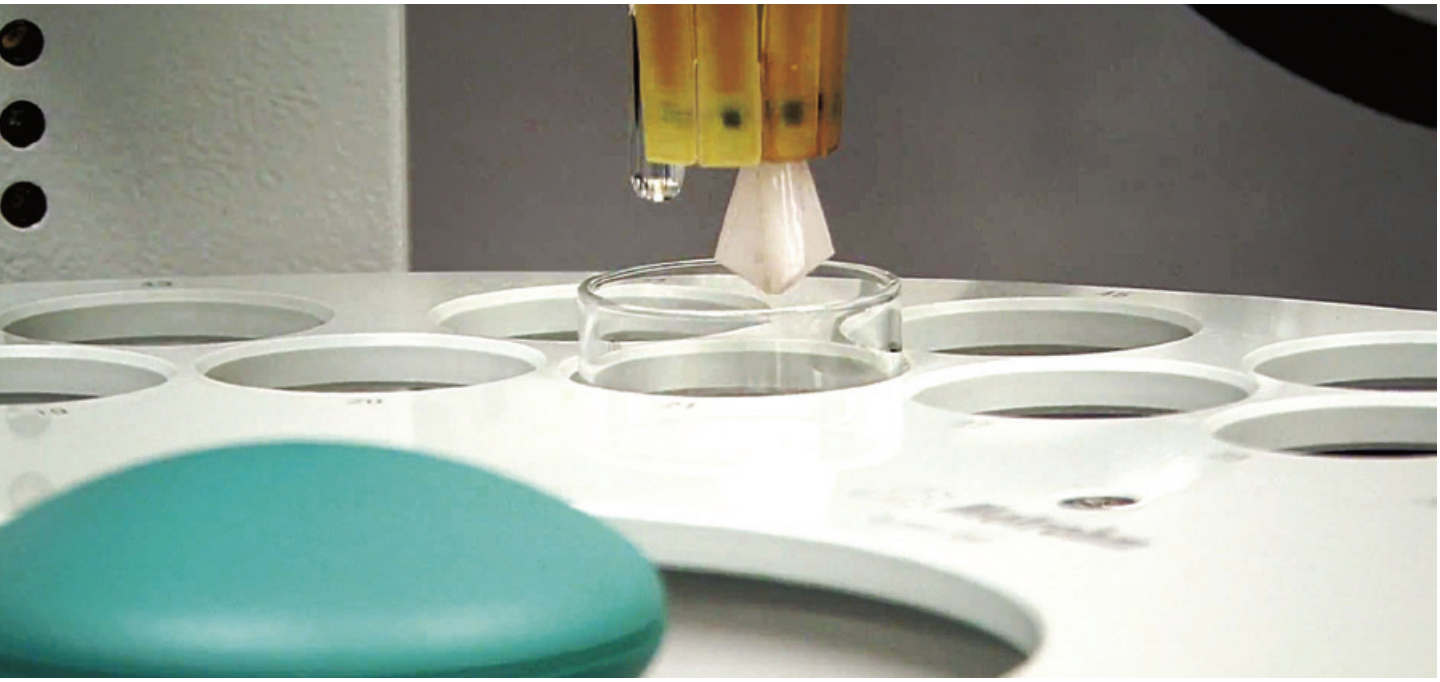


Figure 1. The electronic tongue analysis of the tomato soups. The e-tongue sensors are indicated by umami, metallic, bitter, sweet, spicy, sour, and salty. The triangles represent triplicate measurements. The sensory attributes are indicated in red. The "center" points contain 33.33% of each of the three salts. When only two salts are listed, 50% of each salt is present. When "dom" (dominant) is in the title, this indicates that the first salt is present at 66.67%, with the other salts present at 16.67% each.



reduction strategies to allow for the reduction of salt without compromising the enjoyment of the food by the consumer. One of these strategies is salt replacement, or more specifically replacing sodium chloride (table salt or NaCl) in the food with other salts, such as calcium chloride ($CaCl_2$) or potassium chloride (KCl). However, while $CaCl_2$ and KCl provide a salty perception, they also provide other unwanted sensory changes. KCl has a pronounced bitter, chemical or metallic taste (Sinopoli and Lawless, 2012) while $CaCl_2$, while also described as bitter, possesses sour components (Lawless et al., 2003).

Thus, while salt (NaCl) replacement shows promise, making a product with complete replacement of NaCl with either $CaCl_2$ or KCl simply isn't possible; the resulting food product not being acceptable. But we can replace 'some' of the NaCl with $CaCl_2$ or KCl as NaCl has been reported, to suppress bitterness of both KCl and $CaCl_2$ (Breslin and Beauchamp, 1995). As such, we need an efficient way to identify how these salts can be combined to maintain

While salt (NaCl) replacement shows promise, making a product with complete replacement of NaCl with either $CaCl_2$ or KCl simply isn't possible.

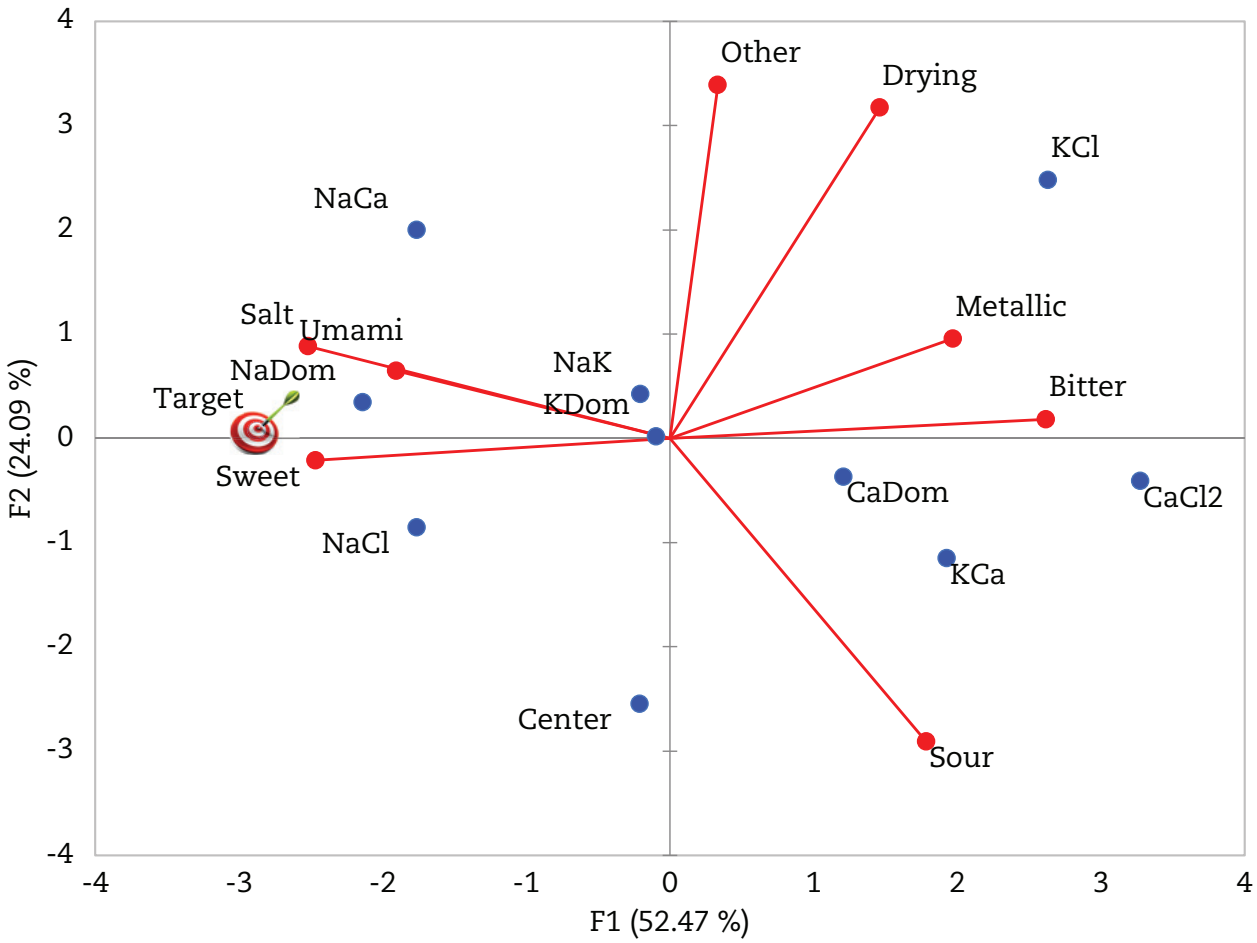


Figure 2. Consumer evaluation of tomato soups and intensity ratings for attributes evaluated by sensory panelists. NaCl, KCl and $CaCl_2$ represent samples containing 100% of that salt. The soup samples are presented in blue with the target representing a 30% salt reduced soup. Samples are named as in Figure 1.

consumer acceptance. To do this, mixture design methodology can be used to determine an ideal combination of these salts to maintain consumer acceptance. Mixture design methodology offers an organised way to combine different salts in different concentrations, resulting in the identification of an ideal blend.

When it comes to evaluating the acceptance of these salt blends, of course we think to use people. Through sensory evaluation, participants can evaluate samples for their acceptance or perception of the intensity of various attributes.

However, beyond using human subjects, the quest to understand the sensory quality of food has led to the application of instrumental approaches to augment human sensory evaluation. The electronic tongue (e-tongue) is a novel instrumental technique recently applied to better understand the gustatory response to non-volatile components in foods, including taste compounds like salt and has allowed for a realistic instrumental measurement of the complex human perception of taste (Ross, 2009). The e-tongue has a sensor array capable of detecting non-volatile compounds in liquid matrices to simulate human taste, detecting sweet, salty, bitter, sour, umami, metallic, and spicy in variety of products including wine (Diako et al., 2017), cheese (Walsh et al., 2020), sweeteners (Waldrop et al., 2016) and spicy compounds (Paup et al., 2018). In addition to giving a response to a specific sensor (i.e. how much

The e-tongue also provides an overall response to a given solution, much like our own tongue.

the salty sensor responds to a given solution), the e-tongue also provides an overall response to a given solution, much like our own tongue. For example, a salty sample may provide a high response on the salty sensor (a specific response), but it may also provide a low response to sour, medium response to sweet, and so on.In addition, while providing a response that is a proxy for human response (but not a replacement), the e-tongue also overcomes some of the challenges associated with sensory evaluation, including panelist fatigue.

Taking this together, this research sought to accomplish several goals:

1. How much NaCl can be replaced with KCl and $CaCl_2$ before consumer acceptance changes?

2. Can we use the e-tongue to detect differences among these salt blends?

To address these questions, various concentrations of NaCl and replacement salts (KCl and CaCl2) were identified with these concentrations based on amounts found in commercially available soup. Using mixture design methodology, ten mixtures varying in their ratios of NaCl, $CaCl_2$ and KCl were prepared in water and in tomato soup. Once prepared, the e-tongue was used to analyse the samples and provide specific responses to the sensors of sweet, sour, salty, bitter, umami and metallic. The e-tongue also provided an overall response which included the response to all of the sensors (mimicking the response of own tongues). Finally, consumers evaluated these different samples for intensities of saltiness, bitterness, astringency, metallic attributes, and provided acceptance scores.

And what did we see? The e-tongue showed high discrimination among the solutions and tomato soup samples, indicating distinct differences among the mixtures of salts (Figure 1). This indicated that the solutions differed in their response to the different sensors. The $CaCl_2$ sample was more defined by the response of the bitter and metallic sensor and NaCl was more defined by the response of the salty sensor. Overall, strong positive correlations (>0.90) between sensory and electronic tongue data were reported.

Consumers also found differences among the mixtures in their perception of attribute intensities, as well as differences in taste. The highest overall taste scores of the consumers were associated with the samples that contained 100% NaCl (Figure 2). With further analysis, including the application of contour plots and desirability function analysis, an optimal replacement value was identified. This blend contained high amounts of NaCl, with lower concentrations of KCl and $CaCl_2$. The initial blend option that resulted in an acceptable salt blend to the consumer was composed of 96% NaCl, 2% $CaCl_2$ and 2% KCl. The second blend that would also be acceptable to consumers was composed of 81% NaCl, 15% $CaCl_2$ and 4% KCl.

From this study, the e-tongue showed promise in the development of products containing different salt formulations to reduce NaCl within processed foods. Given the high discrimination of the electronic tongue, and its strong correlation with sensory analysis, the e-tongue continues to demonstrate great

application for the food industry. While the e-tongue cannot replace human sensory evaluation, the use of the e-tongue could allow for larger sample sets to be evaluated or narrowed without encountering the fatigue and carry-over challenges typical of sensory evaluation. ■

FOR MORE INFORMATION

WASHINGTON STATE UNIVERSITY

Professor, Carolyn F. Ross, Ph.D.
School of Food Science
Washington State University
United States of America
E-mail: cfross@wsu.edu

Carolyn Ross
Professor, School of Food Science
Washington State University

Carolyn Ross is a Professor in the School of Food Science at Washington State University (WSU) and Affiliate Professor in the WSU School of Medicine. She earned her BSc. in foods and nutrition from the University of Manitoba in Winnipeg, her M.Sc. from the University of Guelph in food science, and her Ph.D. from Michigan State University in food science/environmental toxicology. The overall objectives of Dr. Ross' research and graduate education program are to understand the theoretical basis underpinning the sensory perception of foods and wines and correlate these psychophysical attributes with quantifiable characteristics. Since starting at Washington State University in 2004, Dr. Ross has established her lab and the WSU Sensory Evaluation Facility as a center for graduate student training in the areas of sensory science and analytical chemistry. Through this research, Dr. Ross has published over 105 scientific research articles, with over 120 presentations at national and international scientific meetings.

References

Breslin, P. A. S., & Beauchamp, G. K. (1995). Suppression of bitterness by sodium: variation among bitter taste stimuli. Chemical Senses, 20(6), 609–623.

Diako, C., McMahon, K., Mattinson, S., Evans, M., & Ross, C. (2016). Alcohol, Tannins, and Mannoprotein and their Interactions Influence the Sensory Properties of Selected Commercial Merlot Wines: A Preliminary Study. Journal of Food Science, 81(8), S2039–S2048. https://doi.org/10.1111/1750-3841.13389

Lawless, H. T., Rapacki, F., Horne, J., & Hayes, A. (2003). The taste of calcium and magnesium salts and anionic modifications. Food Quality and Preference, 14(4), 319–325.

Paup, V. D., Barnett, S. M., Diako, C., & Ross, C. F. (2019). Detection of spicy compounds using the electronic tongue. Journal of food science, 84(9), 2619-2627.

Ross, C. F. (2009). Sensory science at the human–machine interface. Trends in Food Science &Technology, 20(2), 63-72.

Sinopoli, D. A., & Lawless, H. T. (2012). Taste Properties of Potassium Chloride Alone and in Mixtures with Sodium Chloride Using a Check-All-That-Apply Method. Journal of Food Science, 77(9), S319–S322. https://doi.org/10.1111/j.1750-3841.2012.02862.x

Waldrop, M. E., & Ross, C. F. (2014). Sweetener Blend Optimization by Using Mixture Design Methodology and the Electronic Tongue. Journal of Food Science, 79(9), S1782–S1794. https://doi.org/10.1111/1750-3841.12575

Walsh, E. A., Diako, C., Smith, D. M., & Ross, C. F. (2020). Influence of storage time and elevated ripening temperature on the chemical and sensory properties of white Cheddar cheese. Journal of Food Science.

WHO. (2012). A comprehensive global monitoring framework including indicators and a set of voluntary global targets for the prevention and control of noncommunicable diseases. Geneva: World Health Organization.

One more thing… I forgot to cite the study about salt replacement that is the cornerstone of the article. Here is that citation:

Barnett, S. M., Diako, C., & Ross, C. F. (2019). Identification of a salt blend: Application of the electronic tongue, consumer evaluation, and mixture design methodology. Journal of Food Science, 84(2), 327-338.

Can we assume consum fridges are at a safe temp

By Linda Everis (pictured), microbiologist at Campden BRI

Current UK Food Standards Agency guidance is that chilled foods should be stored at 5°C throughout life even though the legal maximum temperature for chill in the UK is 8°C. A new guidance document, that considers chilled storage temperature, has been developed to further help the food industry set realistic and accurate shelf-lives that maintain product quality and safety.

Food manufacturers understand that their responsibility for the safety and quality of a food extends to the entire life of a product and doesn't end when it leaves their control. They have to consider storage temperatures during distribution, retail and handling by consumers, which prompts them to ask questions such as: "What temperatures will the product be stored at during purchase and in the customer's fridge?"

This is a difficult question to answer. From manufacture to consumer storage, products can encounter a range of fluctuating temperatures as they are passed from one stage of the cold chain to the next. As mentioned above, when it comes to considering what might reasonably happen to food once it has left the commercially controlled environment, producers must consider potential temperature abuse from consumer handling. This is a requirement under the Consumer Rights Act 2015 and has been reasserted in Food and Drink Federation 2017 guidance. For example, when labelling a product to be stored at below 5°C, is it reasonable to assume that it will be stored below 5°C throughout all of its life, or will some of its life be spent at higher temperatures? Answering this question is key as it will have a

ers' perature?

huge impact on the quality of the product as seen by the consumer.

A PRODUCT'S JOURNEY TO A CONSUMER'S HOME

Perhaps 'warm' isn't the first word that pops into your head when you think about the British weather, but even when icepacks and cool boxes are used, the temperature of chilled food products can rise quickly when outside a 5°C fridge. Well-controlled chilled transport is used when delivering chilled products from producers to distribution centres and onto retailers, but the product's remaining journey from the retailer to the consumer's home is usually not under cool conditions. As time spent out of the fridge is one of the primary factors that determine how much a product rises in temperature, we must ask how long it takes consumers to get their food and drinks home.

In 2010, as part of a survey of 329 households, WRAP (Waste & Resources Action Programme) revealed 45% of participants estimated the time from completing the main shop to unpacking was around 30 minutes, with 23% stating this was 30 minutes to one hour. In addition to the time taken to transport shopping home, there is also the time in-store when chilled foods may sit in a shopping trolley whilst the remainder of the shopping is completed, and how about the time it spends sitting on the kitchen counter? It all adds up.

Based on these findings, it is assumed that a period of two hours at 22°C is representative of typical consumer practice when purchasing and transporting chilled foods into the home.

IN THE CONSUMER'S FRIDGE

Assuming some worst-case scenarios, say a food product did reach 20°C, how long would it take to return to 5°C? WRAP's 2010 survey also looked at this question by assessing the time taken for products to return to 5°C after two hours at warmer conditions. Several conditions and times were tested in a number of product types, including sliced ham that was exposed to an hour at 20°C followed by another hour at 30°C while in a standard plastic bag. Once placed in a 5°C refrigerator, the survey found this product was still at the elevated temperature of 10.5°C five hours later.

The time it takes for food to cool isn't common knowledge, so building the assumption that food is almost instantly safe (at 5°C) once placed in the fridge is an easy one for consumers to make. This, however, lulls them into a false sense of security and highlights the need for further

education surrounding this area. WRAP is running a 'Chill the Fridge Out' campaign to educate the public on the need to lower fridge temperatures which will help with this issue, even though the campaign's primary focus is to reduce food waste.

ARE CONSUMERS' FRIDGES AT A SAFE TEMPERATURE?

In 2010, WRAP asked consumers what they thought that the correct fridge temperature should be. Seventy-nine per cent of 329 participants surveyed stated that the temperature should be between 0°C and 5°C. This sounds like great news as it maps perfectly on to industry assumptions and practice. WRAP then surveyed the actual temperatures of 50 consumers' fridges over a four-day period. Only 29% operated at 5°C or less whilst 71% operated at 8°C or less. Eight years on, in 2018, we (Campden BRI) undertook a similar test of 35 fridges over 30 days. The results showed that 53% of them showed readings above 5°C and a further 16% were above 8°C.

These investigations highlight that whilst consumers are aware of what the temperatures should be, this doesn't translate into reality. Let's face it, many fridges do not have a display – digital or non-digital - and how many consumers have thermometers in their fridges to check that they are working correctly?

Generating this type of data at each point of the cold chain, including consumer handling, allows us to better predict the conditions that products experience up until the point of consumption. This, in turn, allows us to put together appropriate shelf-life protocols. Campden BRI's recently updated shelf-life determination guidance, that is backed by expert advice and practical shelf-life assessment, has been aligned with new EU regulation and recommendations for setting a shelf-life. The new guidance which has been extended beyond chilled foods to include ambient stored foods, is now available from Campden BRI. ■

FOR MORE INFORMATION

Campden BRI
food and drink innovation

linda.everis@campdenbri.co.uk
+44(0)1386 842063

Linda Everis, microbiologist at Campden BRI

Bakery sector – Spain

Promoting fashionable ingredients to change perceptions on bread

Irrespective of changing eating habits and consumer needs in the country, bread remains a staple food in the Spanish diet. However, in recent decades bread has come under scrutiny over its healthiness, something that appears to have resonated with some consumers who are concerned about the content of ingredients such as sugar. As a result of this, the industry needs to encourage health conscious consumers in Spain to focus more on functional ingredients when it comes to bread, whilst targeting consumers with fashionable ingredients, such as ancient grains and plant-based ingredients.

In Q3 2019, FMCG Gurus surveyed 1,000 consumers in Spain on their consumption habits when it came to pre-packaged bakery products. These were classified as mass produced items that tended to have a longer-shelf life.

The research also showed that when it came to types of items eaten, bread was a staple food

item in Spain and the country's most popular type of bakery product. A total of 93% of consumers said they eat bread, with 59% eating bread daily. In Spain, meal-time habits are becoming more fragmented, with consumers skipping breakfast and lunch on a more regular basis. They are often replacing larger, formal meals with lighter meals and snacks, which can impact on the bread market. Nevertheless, bread remains a favourite product for consumers, being a popular option for breakfast and lunch with 68% of consumers saying they eat bread in the morning and 66% at lunch time.

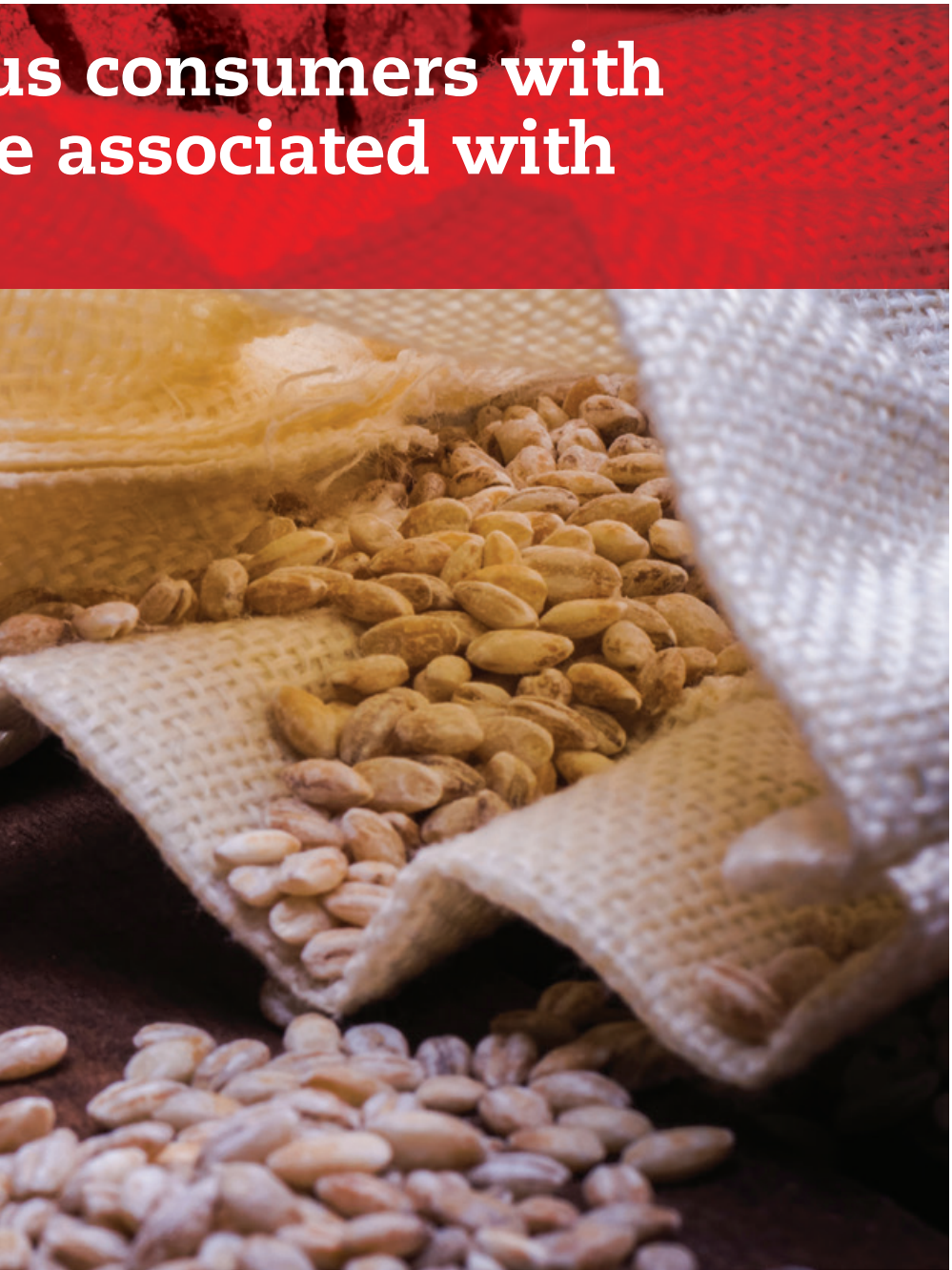
When it comes to eating bread, consumers are becoming more health conscious. This is not surprising given that the number of lifestyle-related health problems such as diabetes continues to rise globally. Consequently, consumers want to know about the nutritional value of products. A total of 48% of bread-eaters in Spain say that they regularly check for sugar content. This is not surprising given the increased awareness of the dangers associated with excessive sugar intake. It is also worth noting that 47% of bread-eaters say that they regularly check for fibre content. This shows that making the right dietary choices is just as

"Brands need to target health conscious newer, fashionable ingredients that are offering a convenient health boost."

big a priority for consumers as is increasing their intake of ingredients associated with a convenient health boost.

Over the last couple of decades, bread has been subject to much scrutiny when it comes to its healthiness. . However, the industry needs to respond to health-conscious consumers who are taking a greater interest in different ingredients. This creates the opportunity to give bread products a more functional and conveniently nutritious positioning. In Q3 2019, FMCG Gurus conducted a survey of 1,000 health-orientated consumers. The research found that 58% looked to improve their diet over the last two years, whilst 45% regularly conducted research into different ingredients.

These behavioural traits are being driven by consumers embracing the concepts of holistic health and healthy ageing, recognising that all aspects of health are interlinked Functional ingredients that offer a health boost beyond basic nutrition is seen as key to achieving this.



This provides an opportunity to promote nutritional boosting beyond traditional ingredients such as protein and fibre. Brands can look to capitalise on new, more fashionable ingredient trends in order to make bread more appealing. For example, a total of only 26% of Spanish consumers who buy bread say that they regularly check for quinoa claims. These ingredients can also create stand-out appeal amongst consumers who are turning to plant-based ingredients as a form of self-expression.

The reality is that lifestyle related health problems such as obesity will continue to grow in Spain, especially as traditional dietary habits continue to evolve, and consumers place more reliance on convenience and processed food. Consequently, bread will continue to be subject to scrutiny about its healthiness. To counteract this, brands need to target health conscious consumers with newer, fashionable ingredients that are associated with offering a convenient health boost. ■

FOR MORE INFORMATION

Mike Hughes
Head of Research and Insight,
FMCG Gurus

This article is based on FMCG Gurus Q3 2019 Pre-Packaged bakery survey in Spain (1,000 consumers) and FMCG Gurus Q3 2019 Active Nutrition survey in Spain (1,000 consumers)

Interview with Anna Breuer

Baking Europe (BE) recently caught up with Anna Breuer, market development manager of global industry team – Food (AB), food machinery speciality lubricant manufacturers Klüber Lubrication Munich, Germany SE & Co. KG.

BE Klüber Lubrication is well-known across the globe for its wide range of lubricants in many industries. For the benefit of those manufacturers who may not be fully conversant, what are the main benefits of using specially designed lubricants for the machines used in the bakery and food industry rather than the standard type of lubricants that might be used, for example, in motor manufacturing?

AB Speciality lubricants for the machines used in the food industry are also known as NSF H1 lubricants. They are in compliance with 21 CFR § 178.3570 issued by the United States Food and Drug Administration. That means they are designed for incidental, yet unintentional food contact, therefore, non-H1 certified products should never be used in and around the food processing area. Correct use of H1 lubricants in theory, means that no contact with food should occur at all.

They are standard nowadays and maintenance managers are aware of that. A common assumption is that H1 products do not perform as well as non-food grade products. But this is not the case for modern H1 products. They offer maximum performance in demanding conditions such as high temperatures and they also contribute to sustainability through reduced energy and water consumption.

BE What are the main criteria that manufacturers need to consider when choosing suitable lubricant solutions?

AB All lubricant products for the food industry should be specially formulated for situations where there is a possibility of incidental contact with food and conform to the strict standards mentioned above. No manufacturer can guarantee that machines won't leak – accidents can and do happen, which is why an annual analysis of potential hazards in a food production plant is essential. NSF H1 registered lubricants are used in case there is an unforeseen leakage. If ordinary mineral oils that are similar to those used in the non-food engineering sector were used,

Correct use of H1 lubricants in theory, means that no contact with food should occur at all.

the end-customer could come to severe harm where for example, it leaked into a food product and was ingested. Back in the day the food industry thought it was sufficient to use H1 products only above the production line but not below. But people are people and errors happen. We also recommend the use of H1 lubricants below the line instead of H2 products thereby helping to increase food safety and efficiency.

BE There are also applications where the contact with food is intentional e.g. for dough dividers or a cutting knife. What kind of products are safe to use in instances such as this to guarantee foodstuff does not adhere to different surfaces?

AB Here, it is important to use processing aids – those that do not present any health risk whilst not having any technological effect on the final product. They should be manufactured from 100% food grade ingredients, free of allergens and mineral oil.

BE Whilst I am not asking for your secret recipe, of course, what are the main constituents of such lubricants – are they vegetable based?

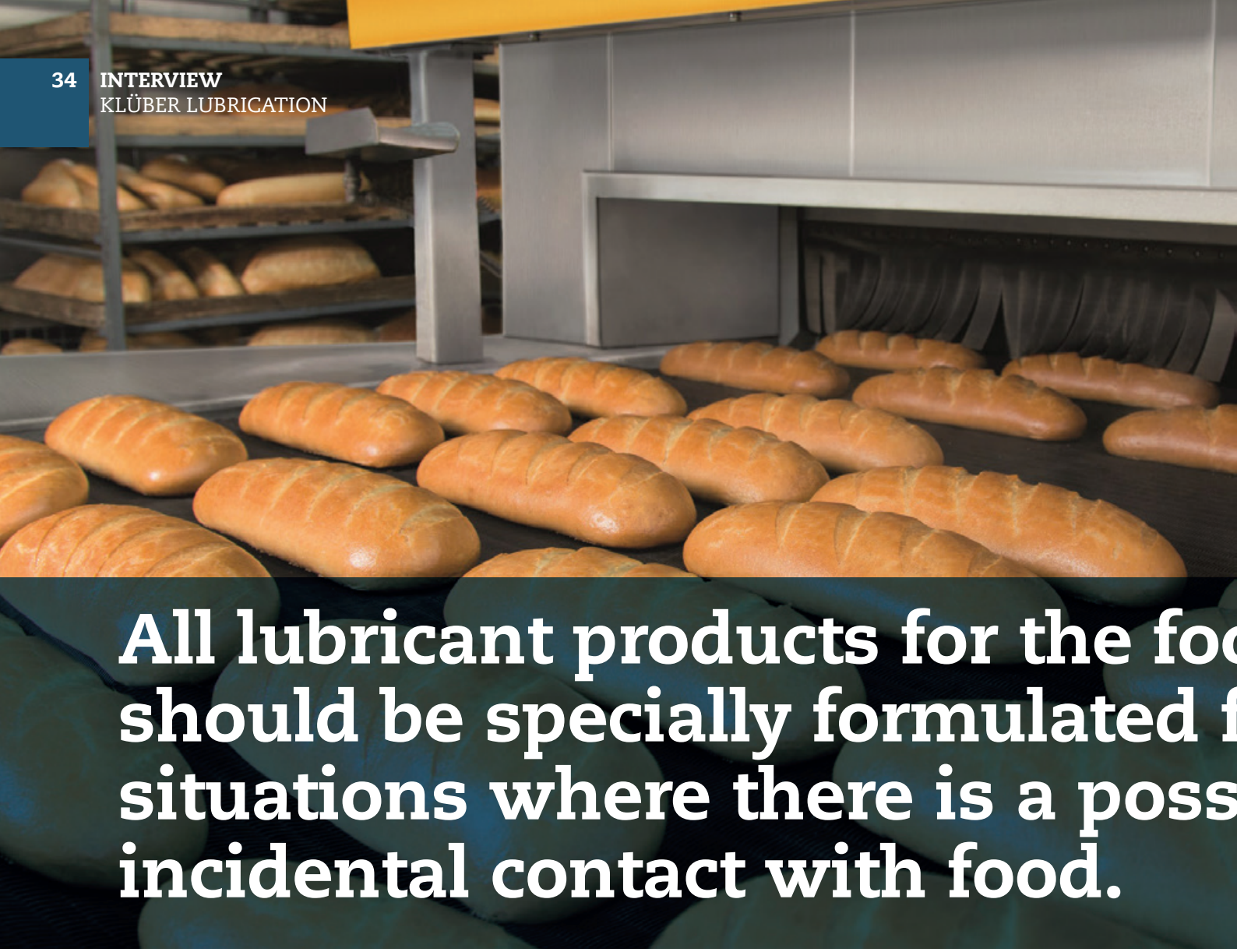
AB No, they are not vegetable based; they are mostly of synthetic origin. The challenges for H1 registered lubricants are that they need to be safe for the consumer whilst performing in the same way as a standard lubricant. The baking industry presents different challenges which include high humidity in bakery provers, high temperatures in baking ovens

or high energy consumption where inefficient heat transfer systems are present. In addition to the unique circumstances encountered in an industrial bakery, extreme conditions such as these create very high stress levels on the machines and moving parts, therefore, a functional and safe set of lubricants must be specified.

BE We touched on H1 but what does HACCP stand for and what does it represent?

AB It stands for "Hazard Analysis and Critical Control Points" and is an internationally recognised method of identifying and managing food safety related hazards by designing control measures. This includes biological, chemical or physical hazards that could make the end product unsafe.

Any company involved in the manufacturing, processing or handling of food products can use HACCP to minimise or



All lubricant products for the foo should be specially formulated f situations where there is a poss incidental contact with food.

eliminate food safety hazards in their production facility. Every defined control point needs to be measured regularly and documented using a protocol.

BE I understand that there are increasing instances of allergies in general across the world. How much of this is from lubricants and what would you advise food manufacturers to do?

AB Instances such as these can arise from cross-contamination during the production process or from machines with poor hygienic design. From our point of view, we advise using safe lubrication which has at least H1 certification. A higher level of safety can be achieved by upgrading to an H1 that has been produced in an ISO 21469 certified production plant.

This will ensure that the way that the lubricants are processed, meet the very highest hygienic standards which in turn ensures that the end products are safe and bolstered by a traceability system if something does go wrong.

BE I understand that anti-microbial additives are now being used in some lubricants, is this true?

AB Food processors must ask the following questions when considering lubricants with anti-microbial claims or properties. Has the lubricant manufacturer secured the appropriate regulatory approvals for any preservative or anti-microbial claim? Is there a verification of legal compliance for the appropriate geographical market E.g.in the European Union, lubricants containing anti-microbial additives fall under the Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) and are considered bio-treated products.

BE What measures can be taken to reduce the danger of microbial contamination?

AB Food processors must be mindful that using a lubricant with anti-microbial properties is no replacement for thorough inspection, cleaning and sanitsation practices – these are still mandatory for a safe and hygienic environment.

BE With regards to the prevention of the above, how important is it, therefore, for a manufacturer to implement a system of monitoring and employee training?

AB For monitoring, a lubrication chart is key, which can be set up with the lubrication provider so the employees know when and, more importantly know how, to change the oil correctly.

Problems can arise, however, when in their efforts to ensure that everything is lubricated properly, that maintenance managers sometimes over or even under-lubricate.

BE Do you, in that case recommend rigorous staff training?

AB Yes, we provide our clients with high performance lubricants but stress the need to apply the correct amount – neither too little nor too much – in order to minimise the risk of contamination. This is why we recommend staff training so the employee knows what he or she is doing and, therefore, carries the appropriate responsibility.

BE There are many producers of food grade lubricants and many different types of product to choose from. How does a bakery plant manager decide which is the best for his plant or application?

AB We ensure that a comprehensive survey is carried out – after all, simply giving a brochure to a producer and asking them to choose a product is completely unsatisfactory for such an important and technically challenging decision to be made.

The lubrication supplier is providing the best solution which is all the more important due to the uniqueness of each bakery plant that I alluded to earlier. In short – lubrication suppliers can not only provide you with the right lubricant but like Klüber Lubrication it goes beyond that. We support our customers globally increasing their efficiency, achieving their sustainability goals and are a reliable partner every step of the way.

This is proven where we have been a partner with a major global food manufacturer for more than 15 years and continue to work globally to deliver improvement based in an ever changing world where objectives are continually changing.

BE And finally, whilst they may seem obvious, what are the potential repercussions for not using suitable food grade lubricants?

AB Well, put simply, the equipment can break down stopping production for an indefinite period of time. Worse still, the consumer could become seriously ill if the correct lubrication system solution and maintenance procedures are not implemented and handled properly.

This could cause irreparable damage to the company's reputation leading to possible plant shut down and even prosecution.

BE Anna, thank you very much for your time today ■

FIND OUT MORE

KLÜBER LUBRICATION

Germany:
Klüber Lubrication München SE & Co. KG
Email Anna.Breuer@klueber.com

United Kingdom:
Klüber Lubrication Great Britain Ltd
Tel: +44 (0) 1422 205115
Fax: +44 (0) 1422 207365
Email: sales@uk.klueber.com

Web: www.klueber.com

MORE DETAILS ON THE BAKINGEUROPE WEBSITE

Understanding the dough adhesion phen – effects of a processing surface

Rita Laukemper, Thomas Becker, Mario Jekle, Technical University of Munich, Chair of Brewing and Beverage Technology, Research Group Cereal Technology and Process Engineering, Freising, Germany

Due to adhesion phenomena, dough often sticks to processing surfaces like stainless steel during the kneading process, or plastic-coated and textile conveyor belts and proving trays – during the transportation and fermentation process. This leads to process disruption, machine-cleaning downtime, reduced output and microbial contamination caused by dough residues. In order to improve the safety and efficiency in bakeries we aimed to develop a better understanding of the interaction between cereal dough and its processing surfaces; and, thereby, to determine processing surface characteristics with a low adhesion to dough.

Apart from the influence of dough characteristics, the material properties of the processing surfaces such as the surface energy and structure (microscopic and macroscopic), play a decisive role in adhesion. The time-dependent adhesion analysis between wheat dough and several bakery relevant materials (stainless steel, plastic coated conveyor belts, proving cloths and baking foils) with different surface energies and microscopic structuring, has shown a clear trend: After a short contact time between both contact partners, the microscopic structuring has a major influence on the adhesion properties, i.e. a higher structuring of some materials can significantly reduce the adhesive strength. After a longer contact time the microscopic structuring becomes less important, whereas the surface energy gains significance since a longer contact time sees the wetting of the whole surface by the viscoelastic dough taking place. Processing materials with surface energy values below $\sigma^{solid\ surface,\ total}$<30 mN/m and a low polar component ($\sigma_{solid\ surface,\ polar}$< 5 mN/m) show significantly reduced adhesion to dough after a longer contact time. Processing materials with energy values $\sigma_{solid\ surface,\ total}$>30 mN/m resulted in high adhesion values to dough, indicating a strong interaction of the two contact partners.

Further experiments showed a high influence of the macroscopic structuring, which determines the contact area formation to dough and thus the active adhesive region. Through the development of an 'imprint' method, the contact area between wheat dough of different properties and its contact surfaces, could be characterised. For this approach, specific surface geometries were constructed using 3D printing of the contact surfaces and the contact point formation, and subsequently the contact area, was determined very precisely depending on the surface structure of the processing surfaces, the dough viscosity and contact time, respectively.

Here again, the contact time plays a decisive role: after a short contact time, a low contact area formation could be detected for a 'grooved structure' (20% compared to a smooth surface); after a longer contact time a 'waffle' structure could prevent the inflow of the dough the most and thus enabled the lowest contact area formation.

The results enable the construction of a specific surface structure with a reduction of the contact area formation and thus a control of adhesion between dough and its contact surface, even after practically relevant contact times. ■


Rita Laukemper

FOR MORE INFORMATION

Dipl.-Ing. Rita Laukemper
Scientific Associate
Technische Universität München
Germany
Email: rita.laukemper@tum.de

The material properties of the processing surfaces such as the surface energy and structure (microscopic and macroscopic), play a decisive role in adhesion.

FORK IN THE ROAD?

With health and wellness trends on the rise in the UK's food and beverage manufacturing sector, how are Companies, Private Equity and Venture Capital reacting to the ongoing disruption from consumers demanding healthier products?

THE CHOICE IS STARK: INNOVATE OR DECLINE

As attitudes towards health, wellness and sustainability continue to cause disruption within food and beverage markets, large companies are being forced to adapt their approach to innovation.

Western markets are under pressure with low growth and input cost volatility, while many heritage products are losing theirrelevance to consumers. Innovative products are satisfying the desire for healthier, more sustainable eating and this is reflected in strong growth performance for these segments.

The food and beverage consumers' demand is changing. As demonstrated by the free-from movement, it is becoming healthier, more transparent and sustainable in its production and packaging.

This shift is also represented in the way new products are undergoing development. With consumers looking for a different experience, companies are responding by widening their product offering.

These dynamics are taking place against the backdrop of lower consumer confidence, fluctuating input costs and uncertainty surrounding Brexit. Adding to this pressure is increasing own-label

competition from traditional grocers and discounters.

Companies are responding by adapting existing product portfolios to meet key health and wellness trends, pushing new product development or acquiring existing brands to improve top-line growth. However, agile start-ups are well placed to deliver successful new product development within the UK's food and beverage (F&B) sector. Large companies are far less nimble than smaller competitors, so it is difficult for large companies to adapt at pace. With the need to get new products to market quickly to exploit these new growth sectors, large companies have been increasingly looking to acquisitions as a means of fasttracking innovation. As an alternative to investing in new product development, acquisitions offer the opportunity for large companies to acquire an emerging leader in a growth segment or channel rather than build from scratch.

PAYING THE PRICE FOR INNOVATION

The market is seeing more and more acquisitions of smaller founder-owned businesses by larger companies as they seek to buy their way into the health, wellness and sustainability sub-sectors. This method of acquisition as a shortcut for innovation is increasing as these emerging sub-sectors continue to show strong growth in an F&B industry that is under pressure to announce regularly improving revenue and profitability figures.

Companies are seemingly willing to pay over the odds for acquisitions in the scramble to exploit these new opportunities. Recent deals, such as Unilever's purchase of graze and Lotus Bakeries' acquisition of Kiddylicious, have taken place for significant multiples.

Based on a median of relevant transactions since January 2015 companies have been willing to pay a median of 14.8x EBITDA for UK health and wellness F&B businesses – 43.8% higher than what would be expected for a typical UK F&B acquisition.

RECENT EXAMPLES OF COMPANY ACQUISITIONS OF UK HEALTH AND WELLNESS F&B BUSINESSES

- Unilever – graze (February 2019)
- Science in Sport – PhD Nutrition (November 2018)
- Finsbury Foods – Ultrapharm (September 2018)
- Lotus Bakeries – Kiddylicious (July 2018)
- Unilever – Pukka Herbs (September 2017)
- Lotus Bakeries – Urban Fresh Foods (December 2015)
- Monde Nissin – Quorn (September 2015).

Large companies are being forced to adapt their approach to innovation.

While on the surface this may appear to be a panicked approach to the pursuit of growth, there are understandable motivations behind these eyewatering deals:

1. Companies need to adapt their existing portfolios to meet long-term shifts in consumer tastes towards health, wellness, and sustainability;

2. These acquisitions are typically strategic investments with less need to generate swift returns in the short run; and

3. Companies can gain significant revenue synergies by expanding the acquired businesses into existing channels or internationally. In addition, cost synergies can be achieved by realigning operations or through increased bargaining power with retailers.

Companies' willingness to pay high prices for quick access to innovation is influenced by the realities of a fast-changing market. Consumer preferences continue to evolve over time, and getting to market quickly is important to avoid missing the boat. Higher multiples mean more pressure to succeed, and making the right choice of company to purchase is paramount. Poor investment decisions are inevitable, however, as consumer preferences shift and trends become outdated. The priority is getting the valuation right, integrating carefully and ensuring a robust strategy.

SELF-SUSTAINABILITY

As large companies begin to accept that traditional models of innovation are no longer working, F&B multinational companies are developing their own innovation units such as SnackFutures, which is part of Mondelez, the global snacking company and owner of the Cadbury brand. Launched in October 2018,

SnackFutures is focused on three key areas:

- Invention of new brands and businesses in key strategic areas.
- Reinvention of small-scale Mondelez brands with large-scale potential.
- Venturing with start-up entrepreneurs to seed new businesses.

HEALTHY COMPETITION?

So, what does this increased M&A activity mean for private individual sellers of businesses and Private Equity? For Private Equity funds, it has meant being priced out of the market for the fastest-growing brands, such as graze. For private individuals, families and founders, who are the owners of most UK F&B businesses and also sell the most UK F&B businesses, this means seriously considering a sale to a larger company.

As the figures show, Private Equity funds saw a significant drop in the number of food and beverage deals completed, from 13 in 2017 to just 5 in 2018. In addition, Private Equity have also had a far smaller presence in acquisitions

of individually-owned businesses, the main owner of food and beverage businesses, falling heavily from 27% in 2017 to 12% in 2018.

Private Equity are clearly nervous of the market's shift towards high multiples and increasing investment in the UK from multinationals, as well as overall market concerns due to the uncertainty over Brexit. This has led to a tendency to be more selective when choosing companies. Naturally being more financially disciplined than companies, Private Equity are typically reluctant to pay over the odds for acquisitions due to their financial requirements, which stipulate an internal rate of return of at least 20% within three to five years. Any high-entry multiple will also require a high multiple on exit, which is not a surety.

WHAT ARE THE PRIVATE EQUITY STRATEGIES IN UK F&B?
There are three primary strategies for Private Equity to follow:

1. Build relationships with companies who wish to remain independent

This approach will increasingly require extensive searching, building relationships with owners and management teams, particularly when owners have a strong conviction to remain independent. This will come with deeper and more complex planning, as Private Equity tend to require defined entry and exit plans before taking the plunge. This approach allows smaller funds to get involved, and can feature deals that would be too small to appear on larger companies' radar. In addition, this can be very attractive for entrepreneur-led companies who do not wish to be swallowed up by a large corporate but simply wish to retain their own culture and values while gaining financial support for the next step of the journey.

In November 2018, Inverleith, a Scottish Private Equity fund who typically acquire businesses with revenues of £5 to £30 million, acquired a controlling stake in Montezuma, a founder-owned UK luxury chocolate brand that had seen success with a range of vegan, freefrom and ethical products. Helen and Simon Pattinson, the founders, were keen to find a suitable investment partner who shared their values and could take the business to the next stage of growth. Following the deal, the Pattinsons stepped away from management roles and took ambassadorial roles and director positions in the business.

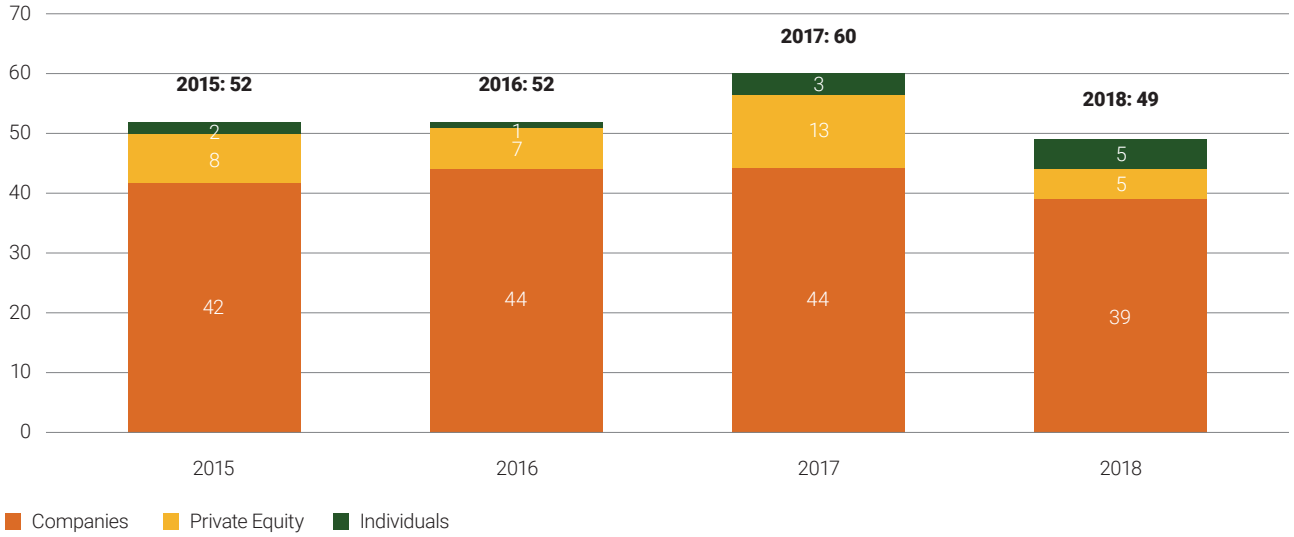
2. Acquire existing unloved brands and pivot their offerings to match new trends

This strategy can take the form of acquiring an existing brand in an unhealthy segment that could be developed into a healthier offering. This would typically require development capital expenditure, as well as a management team with a clear, executable vision for turning the brand around. An example is KKR's acquisition of Unilever's spreads division in July 2018 in a mega £6 billion deal, with potential plans to improve profitability and pivot the Flora brand into healthier and natural segments.

3. Buy and build a business

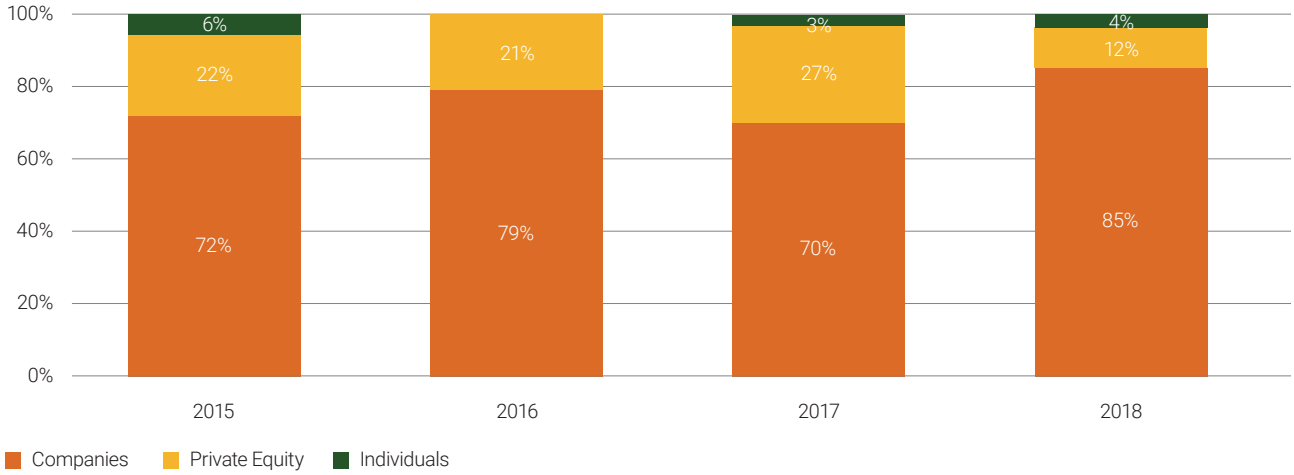
This strategy is typically pursued by larger Private Equity funds that have the capacity to acquire a number of businesses over a period of time. CapVest, who established Valeo Foods in 2010, have undertaken a complex strategy of acquiring eight businesses and increased the EBITDA to well in excess of €100 million from approximately €20 million in 2010. This approach requires extremely careful orchestration both in convincing owners to sell to them and also the ability to integrate

FIGURE 1: NUMBER OF UK F&B ACQUISITIONS BY TYPES OF ACQUIRER



Note: Private Equity acquisitions exclude bolt-on deals by existing Private Equity owned companies
Source: AlixPartners research, Mergermarket

FIGURE 2: ACQUIRERS OF F&B BUSINESSES OWNED BY INDIVIDUALS



Note: Private Equity acquisitions exclude bolt-on deals by existing Private Equity owned companies
Source: AlixPartners research, Mergermarket

Combined with a difficult macro backdrop, established companie forced to adjust their strategies t

successfully a wide range of organisations.

DEBT MARKET VIEWPOINT
Unlike other sectors, where credit funds account for approximately 50% of term-lending, the UK food and beverage lending activity is dominated by banks. Midmarket debt activity remained broadly stable in 2018, with notable UK bank deals in the midmarket included NIBC and Lloyds supporting Exponent's acquisition of Meadow Foods and the amend to extend of ComplEAT Food Group's banking facilities by HSBC and SMBC, owned by Equistone.

NOTHING VENTURED
Venture Capital, whose traditional focus has been the technology sectors, have also woken up to the possibilities of the free-from F&B sector in a big way. Major Venture Capital firms such as Balderton and relative newcomers such as PowerPlant Ventures, New Crop Capital and Stray Dog Capital have focused on pumping money into innovative plant-based meat start-ups such as Beyond Meat in a bid to find a winner in this emerging growth market. The size of the prize is potentially huge as illustrated by Beyond Meat's $1.5 billion IPO and Burger King's partnership with Impossible Foods, another plant-based substitute business, to produce the meat-free Whopper burger.

BREXIT PERSPECTIVE
These disruptive health, wellness and sustainability forces are expected to continue for the long-term. However, depending on what kind of Brexit is reached, there will likely be manufacturing realignments in the short run, with companies seeking to bolster their presence in the UK, in mainland Europe or outside the EU, dependent on their end customers.

Regardless, UK brands will continue to provide significant new product development. British brands translate well across the globe due to significant innovation, use of quirky branding, high degree of product trust and the vast reach of the English language.

CONCLUSION
The mega-trends of health, wellness and sustainability are disrupting the F&B industry. Combined with a difficult macroeconomic backdrop, established companies are being forced to adjust their strategies to survive. With squeezed margins and higher price points on acquisitions increasing the pressure to succeed, companies must pursue robust planning on target identification, valuation and integration. This aggressive buying of innovation requires a clear-minded operational, organisational and strategic approach, but can offer inroads into growth markets for players who are adequately prepared.

Private Equity must also shift its acquisition strategy, moving off-market and connecting with owners who wish to retain independence while gaining investment. The need for careful targeting and screening here is paramount and Private Equity need to be very smart in selecting the correct winners, turning around an unloved brand or following a sophisticated buy-and-build strategy, which comes with its own execution risks. The proliferation of food tech start-ups will also see greater activity from Venture Capital, or Company-backed Venture Capital funds who are willing to take greater risks in order to unearth the hidden gems of the future.

Realising the opportunities of F&B's growing health, wellness and sustainability sectors will require a mix of boldness, care and planning. If traditional players and new market entrants want to thrive in this rapidly evolving environment, they must update their approaches and think differently to win in the F&B market over the long-term. ■

economic
s are being
o survive.

FOR MORE INFORMATION

AlixPartners

Andy Searle
Managing Director - Consumer Practice
AlixPartners
Asearle@alixpartners.com

PRINTED POWER
Electricity generation for indu

Recent global and local events have highlighted the need for immediate action to combat climate change and transition the global energy profile. Expert judgement suggests that climate change has reached a crisis point and scientific and public opinion is agreed that CO_2 emission and fossil fuel usage must immediately be curtailed.

In light of this growing change in beliefs governmental policy must and will follow suit. Indeed, most western countries have already committed to expansive renewable energy growth and rapid transitioning of energy production away from fossil fuels. For example, the UK has brought forward a full ban on selling new petrol, diesel or hybrid cars to 2035[1]. In announcing this policy change, U.K. Prime Minister, Boris Johnson stated that 2020 will be a "defining year of climate action" for the planet.

While conventional (silicon-based) solar energy will continue to improve and play a significant role in the new energy generation mix, a suite of renewable technologies is urgently required to transition the global energy profile. One new photovoltaic technology which can contribute significantly to future energy needs, organic photovoltaics, has made rapid advances in the past five years. Indeed, currently devices of up to 18% efficiency have been demonstrated in the laboratory; comparable to typical efficiencies of the best roof top silicon modules[2].

THE TECHNOLOGY

Organic photovoltaics (OPVs) are based on the unique properties of semiconducting organic (carbon-containing) molecules and polymers. These materials consist of alternating double and single carbon bonds, and it is this bond arrangement that is the origin of their electrical properties while their chemical structure determines their physical nature. The defining feature of these materials is that they combine the flexibility,

Devices of up to 18% efficiency have been demonstrated in the laboratory; comparable to typical efficiencies of the best roof top silicon modules.

ustry and business

formability and economy of plastics with the technological capability of electronics; creating the tantalising vision of coating every roof and other suitable building surface with low-cost photovoltaics[3].

The way in which electrcial currents are generated in conventional silicon solar cells is well established. In these solar cells, sunlight landing on a panel produces a photocurrent only at junctions between two different types of silicon: a p-type semiconductor that is richer in positive charges (holes) and a n-type semiconductor that is richer in negative charges (electrons). The energy from the sunlight is enough to photoexcite holes and electrons from the junction region that are immediately separated migrate to the opposite electrode, whereupon they can do useful work.

However, in an OPV device, the physics of the materials means that incident sunlight produces an electron and hole that are still bound to eachother (a bit like the proton and electron in an atom). This bound electron-hole pair (which is known in physics-speak as an exciton) can

Cost of electricity (AU$ per kwh) for printed solar cells of varying efficiency and lifetime.

Lifetime (Yrs) \ Efficiency	1	2	3	4	5	10
1	0.95	0.51	0.37	0.29	0.25	0.16
2	0.59	0.33	0.24	0.20	0.18	0.12
3	0.47	0.27	0.20	0.17	0.15	0.11
4	0.41	0.24	0.18	0.16	0.14	0.11
5	0.37	0.22	0.17	0.15	0.13	0.10
10	0.30	0.19	0.15	0.13	0.12	0.09

SO WHERE TO FOR BAKING?
The question then remains, what are the likely implications for energy intensive businesses; in particular, the baking industry. Lets consider a small bakery comprising 4-5 employees making a few hundred loaves of bread per day on premises that are around 150m^2. If we assume (based on 2019 UK studies[7]) that a kilogram of bread requires 0.18kwh of electricity to produce, then our small bakery will consume around 60kwh a day for baking bread. Lets now assume that we cover the roof of this bakery with printed solar with an efficiency of 2%. These solar cells will produce on average 15kwh a day; corresponding to one quarter of the energy consumption of the bakery. It is clear, therefore that as the efficiency of these cells increases over the next few years, printed solar could play a significant role in offsetting the electricity costs, and thus increasing the sustainability, energy intensive industries such as bakeries.

Large area printed solar technology can compete with coal generated power.

only migrate over a very short distance (~10 nanometres or about one twenty thousandth of the width of a human hair) before recombining either to give off light (photoluminescence) or heat. Thus, in order obtain useful work from an OPV device, these photo-generated excitons must be separated and the charges collected within a few nanometres of eachother. Fortunately, this separation readily occurs at interfaces, or junctions, between different organic electronic materials to produce positive and negative electrical charges, which then travel to the electrodes to produce current. As such, the most efficient devices consist of a mixture (or blend) of a p-type semi-conducting polymer, which readily accepts and transfers positive charges (holes), and a n-type material that readily accepts and transfers negative charges (electrons).

COE solar inks synthesised at the University of Newcastle.

Blends of p-type and n-type materials produce a large number of interfaces throughout the material at which charge separation of the excitons can occur. Conventionally, OPV devices are fabricated from mixtures of donor and acceptor organic electronic materials, which are deposited to produce the interpenetrating network needed for the ready separation of electrical charges in the solar cell[4]. Current fabrication methodologies rely on the thermodynamics of demixing to produce phase segregated regions with the required optimum size of 20–50nm[5].

FROM BENCHTOP TO ROOFTOP

The world leading Centre for Organic Electronics (COE) at the University of Newcastle, Australia, has been focussed for many years on the design, fabrication and characterisation of large scale printed solar technology with the goal of translating the technology from the laboratory into business and industry.

The COE team has undertaken extensive economic modelling of both the module cost and levelised cost of energy for commercial-scale printed solar devices and have shown that, with only modest device efficiency and lifetimes, large area printed solar technology can compete with coal generated power For example, 3-5% devices with 3-5 year lifetime provide electricity at a LCOE competitive with current generation and that OPV modules can be fabricated at scale and installed at a cost of AU$10/m^2.

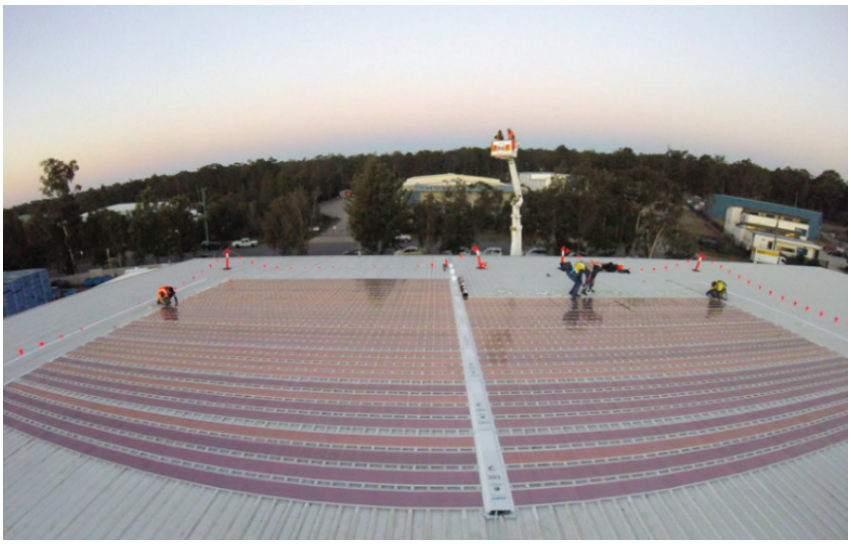
Additionally, the COE has established extensive facilities for upscaling the production of the required organic electronic materials by adapting existing chemical synthesis to enable production at large scale, thus dramatically lowering costs. For example, by tuning reaction conditions to reduce synthetic complexity and avoiding expensive purification, reaction

yields are maximised while solvent use and waste are minimized.

DEMONSTRATION INSTALLATIONS

The COE has established a programme of printed solar installations with commercial partners across Australia and internationally[6]. The efficiency of these initial pilot scale installations is around 1-2% with a lifetime of 1-2 years; corresponding to an at scale cost of electricity as low as AU$0.33 per kwh. The COE team is already trialling new materials and architectures that will deliver higher efficiencies and lifetimes, which are planned to be available following the completion of these pilot demonstrations. ■

COE printed solar cells (above) and Installation of R2R solar modules: COE team rolling out 200m² of printed solar.



FOR MORE INFORMATION

Prof Paul Dastoor
Director, Centre for Organic Electronics
University of Newcastle,
NSW Australia
Email: paul.dastoor@newcastle.edu.au

REFERENCES

1. https://www.bbc.com/news/science-environment-51366123 (accessed Feb. 15, 2020)
2. Liu, Q.;Jiang, Y.;Jin, K.;Qin, J.;Xu, J.;Li, W.;Xiong, J.;Liu,J.; Xiao, Z.;Sun, K.;Yang,S.; Zhang,X.; Ding, L. 18% Efficiency organic solar cells, Science Bulletin, 2020, 65, 272-275.
3. Brabec C, Dyakonov V, Scherf U. Organic photovoltaics. Weinheim: Wiley-VCH; 2008.
4. Günes, S.; Neugebauer, H.; Sariciftci, N.S. Conjugated polymer-based organic solar cells. *Chem. Rev*.2007, 107, 1324–1338.
5. Yang, X.; Loos, J. Toward high-performance polymer solar cells: The importance of morphology control. *Macromolecules2007*, 40, 1353–1362.
6. https://theconversation.com/new-solar-cells-offer-you-the-chance-to-print-out-solar-panels-and-stick-them-on-your-roof-102335
7. Lopez-Aviles, A.; Veldhuis A.; Leach, M.; Yang, A. Sustainable energy opportunities in localised food production and transportation: A case study of bread in the UK. *Sustainable Production and Consumption2019*, 20, 98–116.

RONDO
Dough-how & more.

RONDO Industrial Solutions

- More than 30 Years of Experience
- More than 3000 Installations world-wide
- Swiss Precision Engineering
- Highest Performance and Capacity
- Ground-breaking Hygiene Standard (ASTec)

interpack
PROCESSING & PACKAGING

Visit us at booth 3E54 in hall 3.

www.rondo-online.com

RONDO Industrial Solutions
RONDO Burgdorf AG, 3400 Burgdorf/Switzerland, Phone +41 34 420 81 11, info@rondo-online.com
RONDO Schio s.r.l., 36015 Schio (VI)/Italy, Phone +39 0445 575 429, info@rondo-online.com