facts

New generation of healthy baking powder

Excellent baking results, zero sodium contribution and substitution of phosphates

Jungbunzlauer
From nature to ingredients®

Introduction

Important formulation trends in industrial baking are sugar reduction, fat reduction and sodium reduction. Sodium reduction is of particular interest to regulators because of the potential health risks: high intake of sodium is associated with increased blood pressure and higher risk of cardiovascular disease, stroke and coronary heart disease[1].

Public Health England, the executive agency of the Department of Health (DoH), published sodium limits in 2012 and revised them in 2017[2]. For the category Cakes and Biscuits the sodium targets were reduced from 200mg/100g to 170mg/100g sodium.

Major sodium contributors in bakery products are the phosphates, like SAPP and SALP, and sodium bicarbonate – all constituents of baking powder.

Table 1: Sodium content of ingredients used in standard baking powder

Baking powder ingredient	Chemical formula	Molecular weight (g/mol)	Sodium content %
SAPP	$Na_2H_2P_2O_7$	221.94	20.7
SALP	$NaH_{14}Al_3(PO_4)_8 \cdot 4H_2O$	145	15.9
Sodium bicarbonate	$NaHCO_3$	84.01	27.4

For a standard cake or biscuit product, the usual baking powder consisting of sodium-containing phosphates and sodium bicarbonate will contribute to a sodium content of about 300 – 400mg/100g. Hence product developers are approaching the limits for achieving sodium reduction targets with commonly used ingredients.

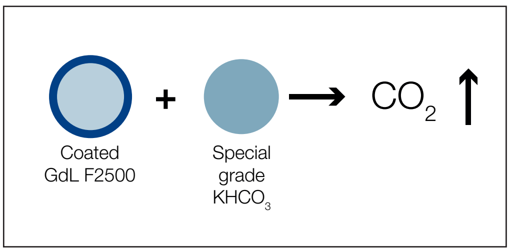
Options for reducing sodium in baking powder include replacement of SAPP by monocalcium phosphate (MCP), as proposed by phosphates producers[3]. Alternatively potassium bicarbonate can be used instead of sodium bicarbonate.

Table 2: Baking powder ingredients with zero sodium content

Baking powder ingredient	Chemical formula	Molecular weight (g/mol)	Sodium content %
MCP	$CaH_4P_2O_8$	234.05	0
GdL	$C_6H_{10}O_6$	178.14	0
Potassium bicarbonate	$KHCO_3$	100.11	0

We propose a system based on two components that can eliminate **100% of the sodium content from the leavening system.** It is based on a special product form of glucono-delta-lactone (GdL) and potassium bicarbonate ($KHCO_3$) and has been proven to be stable during storage under normal conditions, thanks to microencapsulation of the glucono-delta-lactone.

Figure 1: Concept of sodium-free baking powder based on microencapsulated GdL



Major advantages of this baking powder system are:

a) Zero sodium contribution, does not contain sodium or phosphates
b) The rate of reaction (dependant on type of baking goods) can be modulated via the coating thickness
c) Reactive system is stable during storage for 6 months

Baking powder ingredients

Microencapsulated GdL

GdL has long been used as a raising agent. However, a characteristic of GdL is that it will react with the base (usually sodium bicarbonate) to continuously produce CO_2 with longer holding times.

Furthermore, our own studies showed that GdL in combination with potassium bicarbonate is not stable in a sachet or premix due to the higher hygroscopic properties of the potassium bicarbonate.

A solution that overcomes both challenges is microencapsulation of the GdL using a hydrogenated vegetable oil. The encapsulated GdL gives a slower reaction during dough preparation and is much more stable in combination with potassium bicarbonate during storage. We found out that a 15% or 20% coating is effective in protecting the GdL for stability purposes in combination with potassium bicarbonate and for the desired rate of reaction during dough preparation[4].

Potassium bicarbonate

A standard potassium bicarbonate from Evonik (FK grade) was milled to a particle size similar to the microencapsulated GdL products.

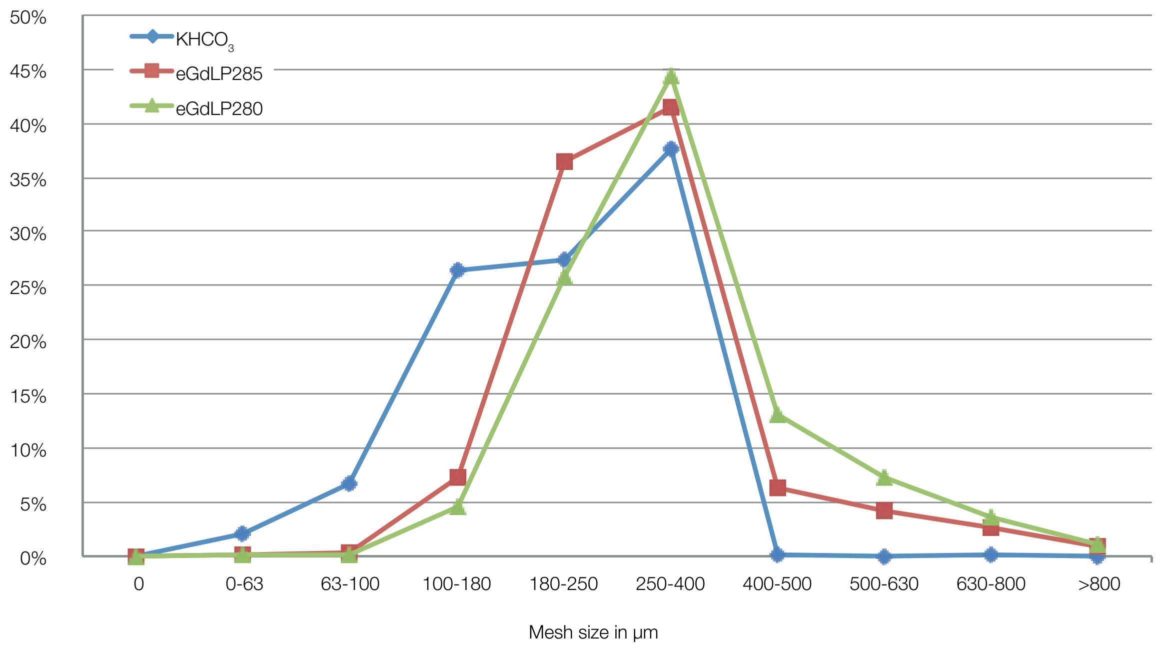
All baking powder ingredients used in this study are summarised in table 3.

Table 3: Ingredients used in the study for sodium reduction of fine baked goods

Ingredient	Abbreviation	Acitivity	Commercial product	Supplier
microencapsulated Glucono-delta-Lactone 85%	eGdL 85%	85%	eGdLP285	Jungbunzlauer
microencapsulated Glucono-delta-Lactone 80%	eGdL80%	80%	eGdLP280	Jungbunzlauer
Glucono-delta-Lactone	GdL	100%	GdL F2500	Jungbunzlauer
Sodium acid pyrophosphate	SAPP28	100%	Levall AR 28	Buddenheim
Sodium bicarbonate	$NaHCO_3$	100%	BICAR®Food 0/13	Solvay
Potassium bicarbonate	$KHCO_3$	100%	$KHCO_3$ Type A	Evonik/ Jungbunzlauer

The typical particle size distributions of the microencapsulated GdL and milled potassium bicarbonate are shown in figure 2.

Figure 2: Particle size distribution of microencapsulated GdL and $KHCO_3$



Results for stability of baking powder compositions

The stability of the baking powder is of key importance because the reactive mixture is stored as a combination of the acid and base. In industrial premixes with flour, a residual humidity of 15% is typical, so to be useful any baking powder needs to be stable during storage even in the presence of humidity. In order to evaluate the storage stability of the baking powder, sachets of mixtures in presence of corn starch were stored either at ambient conditions or, for stressed storage, at 35 °C and 75% relative humidity. The baking powders were analysed for the amount of carbon dioxide generated before and after storage using the Tillman-Heublein method[5].

With storage at room temperature (figure 3) the recovery rates after six months showed the stability of the combinations of encapsulated GdL with $KHCO_3$ to be excellent. Only the combination of the non-coated GdL/$KHCO_3$ showed a significant decrease of CO_2 recovery to less than 80%.

For the stress storage (figure 4) the recovery rates after four weeks were: 80% for the benchmark SAPP/ $NaHCO_3$; 70% for the combination of eGdL80%/$KHCO_3$; and less than 60% for the combination eGdL85%/$KHCO_3$.

No measurement was possible for the combination GdL/$KHCO_3$, because of premature reaction of components in sachets.

Figure 3: **Recovery rates in % of theoretical CO_2 volumes after storage at room temperature 21°C / 50% rel. humidity**

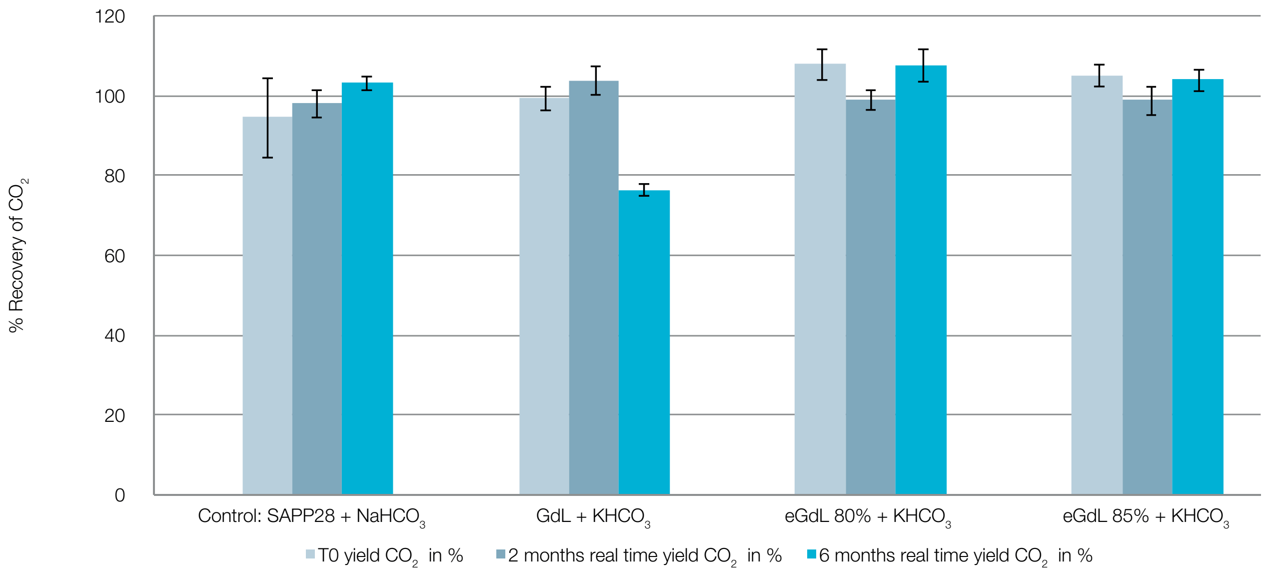
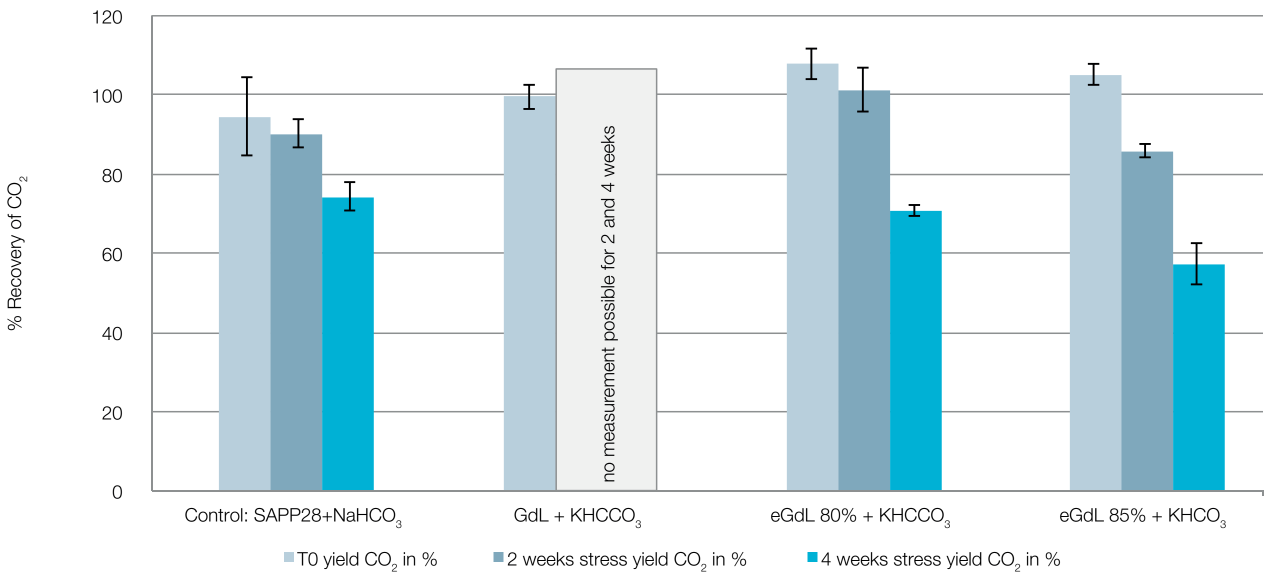
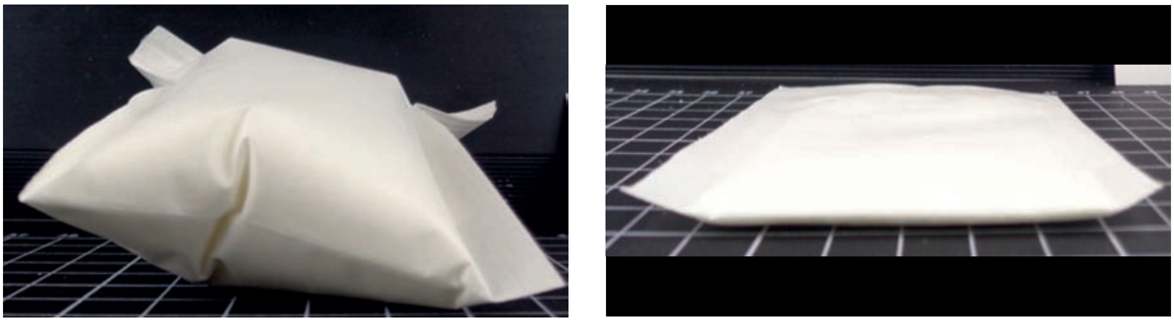


Figure 4: **Recovery rates of theoretical CO_2 volumes after storage with stress climate 35°C / 75% rel. humidity**



The visual inspection of baking powder sachets was very revealing (figure 5). After storage for six months the sachet of non-coated GdL with potassium bicarbonate was inflated (unstable), while the sachet containing microencapsulated GdL with potassium bicarbonate was flat (stable).

Figure 5: Baking powder sachet filled with GdL / potassium bicarbonate / corn starch (left) and a sachet filled with encapsulated GdL (80%) / potassium bicarbonate / corn starch (right) after six months storage at 21°C / 50% rel. humidity



Results for dough rate of reaction (ROR)

The amount of carbon dioxide developed during the preparation of dough was determined using a Risograph instrument (National Manufacturing, a Division of TMCO Inc, USA)[6]. The mixtures contained 20 g hi-gluten flour and 30 g water with an amount of baking powder that was calculated to give the same amount of carbon dioxide for each mixture. The mixtures used are shown below (table 4).

Table 4: Baking powder combinations for Risograph tests (all entries in g)

Ingredient	Blank ($NaHCO_3$)	Standard	Control	eGdLP280/ $KHCO_3$	eGdLP285/ $KHCO_3$
Hi-Gluten Flour	20	20	20	20	20
$NaHCO_3$	0.5	--	--	--	--
$KHCO_3$ Type A	--	0.6	0.6	0.6	0.6
SAPP	--	0.68	--	--	--
GdL F2500	--	--	1.11	--	--
eGdL 80%	--	--	--	1.39	--
eGdL 85%	--	--	--	--	1.31
Water	30	30	30	30	30

The curves in figure 6 detail the cumulated CO_2 development over time of the baking powder combinations with sodium bicarbonate at 25°C. The benchmark combination SAPP28/$NaHCO_3$ reached a total CO_2 development of 15% after 60 min. The non-encapsulated GdL in combination with $NaHCO_3$ reached a total CO_2 development of 50% in the first 60 min. For the combination eGdL80%/$NaHCO_3$, the CO_2 development remained below the benchmark for the first 17 min and rose to 30% at 60 min. The combination eGdL85%/$NaHCO_3$ showed behaviour more similar to the non-encapsulated GdL and reached a total CO_2 development of 47% after 60 min.

Figure 6: Risograph curves of CO_2 development with a combination of encapsulated GdL and sodium bicarbonate at 25°C (standard: SAPP28 / KBC; benchmark $NaHCO_3$)

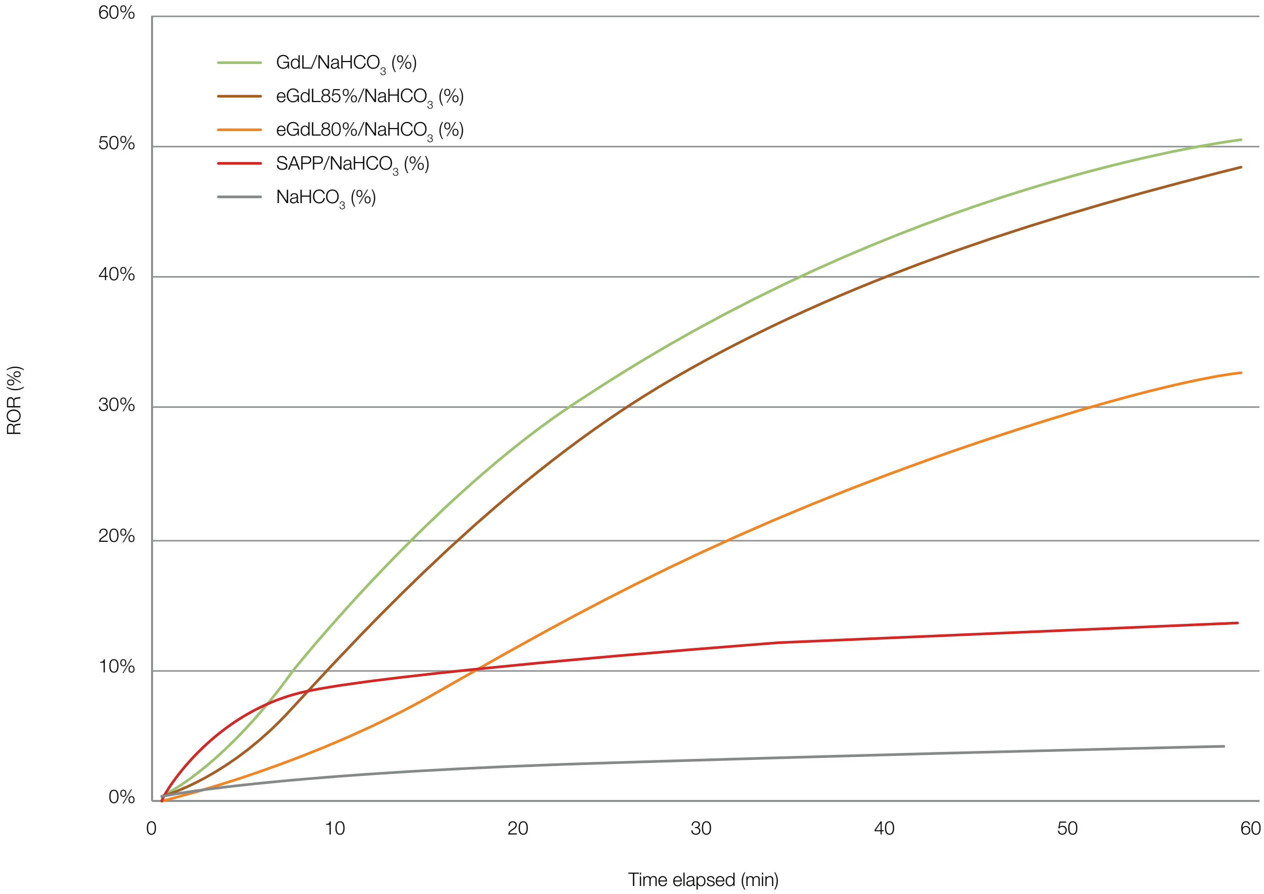
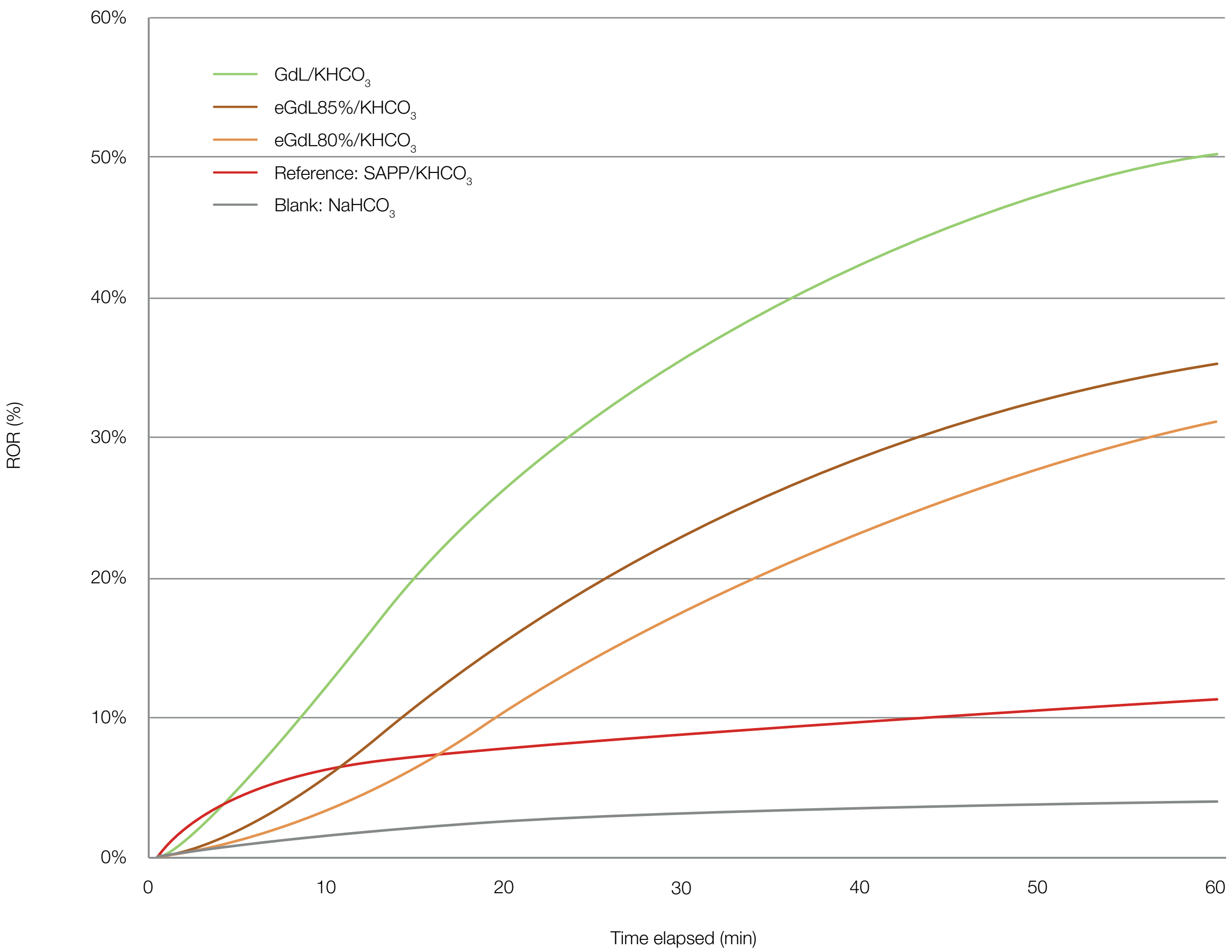


Figure 7 summarises the CO_2 development of the combinations of leavening acid and $KHCO_3$ at 25°C: The situation looked different for each of the four combinations: eGdL80%/$KHCO_3$ released 31% and the system eGdL85%/$KHCO_3$ released 35%, whereas the non-encapsulated GdL released 50% of the theoretical amount of CO_2.
After 15 min the curves for the two encapsulated GdL are close to the reference combination SAPP 28/$KHCO_3$.

Figure 7: Risograph curves of CO_2 development of combination of encapsulated GdL and potassium bicarbonate at 25.0°C (standard: SAPP / KBC; benchmark $NaHCO_3$)



In summary, the rate of reaction is strongly influenced by the microencapsulation of the GdL. The amount of coating was chosen to simulate the standard SAPP 28. Technically, the coating could be further enhanced to provide even slower action GdL types.

Results of baking trials

Two different typical recipes, a muffin and a scone, were chosen to assess baking performance, and baked under different conditions.

The analytical assessment was performed using the following methods:
1. Volume was measured with a National Cereal Chemistry Equipment "pup" loaf volumeter (reads 400 – 900 cm^3) standardised with a 400 cm^3 block
2. The weighed biscuit/muffin was then cut in half and the highest point was measured and recorded in mm using a digital calliper
3. Pictures were taken of the cross-section and top of each variable (2 cm slice)

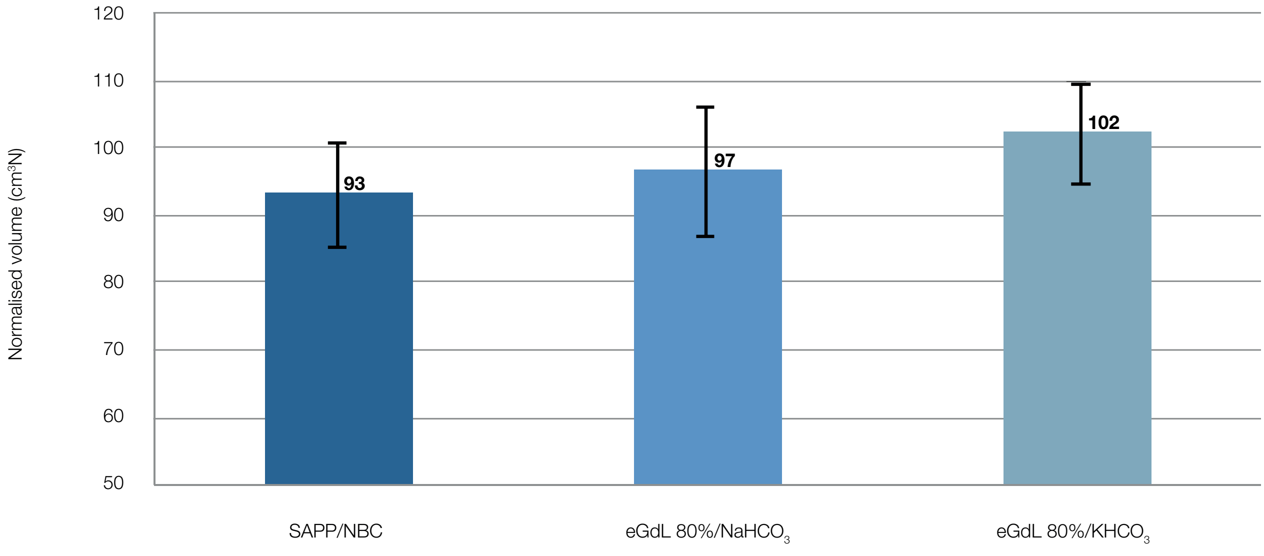
Baking trials muffins
A simple recipe was used for the muffins (see table 5). The baking conditions were set at 177°C (350°F) in a conventional oven for 21 – 25 minutes. Six specimens were produced per baking powder combination and the standard deviation displayed in the figures.

Table 5: Muffin recipe for baking powder combinations with $NaHCO_3$ or $KHCO_3$

Ingredient	Baker's % NBC	Baker's % KBC
Flour	100.0	100.0
Dried whole egg	7.0	7.0
Non-fat dry milk	3.0	3.0
Salt	0.5	0.5
Baking powder	2.8 – 4.5	3.1 – 4.8
Vegetable oil	20.0	20.0
Water	63.0	63.0
Sugar	50.0	50.0
Total	**246.3 – 248.0**	**246.6 – 248.3**

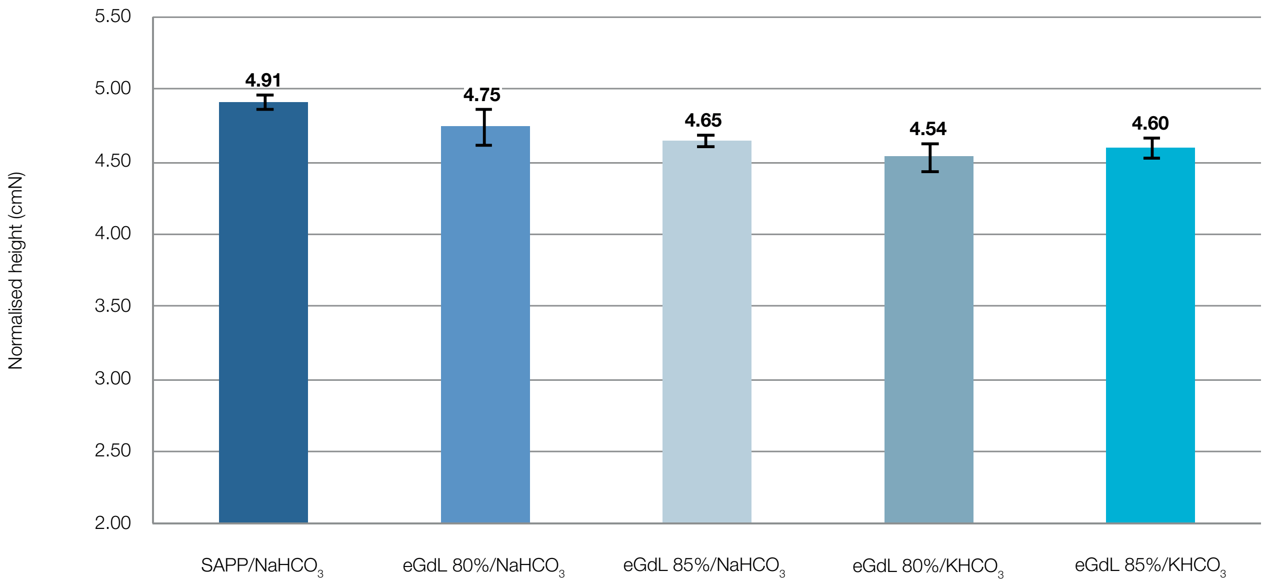
The baking results for the muffins showed a slightly higher volume for the encapsulated GdL in combination with $NaHCO_3$ and $KHCO_3$, although the differences were not statistically significant.

Figure 8: Normalised volume of the muffins baked with eGdL80%/$NaHCO_3$, eGdL80%/$KHCO_3$ and SAPP28/$NaHCO_3$ (reference)



The comparison of the height of the muffins (figure 9) showed that the combination eGdL80%/$NaHCO_3$ performed slightly better than the eGdL85%/$NaHCO_3$. The combinations of eGdL80%/$KHCO_3$ and eGdL85%/$KHCO_3$ produced muffins with a slightly lower height. None of the four combinations were able to match the height of the reference completely.

Figure 9: Comparison of normalised height of the muffins incl. standard deviation. Reference is SAPP28/$NaHCO_3$



The results of the visual inspection in the muffin baking trials are shown below. The crust of the eGdL/$KHCO_3$ samples was slightly brighter and the crumb had a comparable structure to the reference. It even showed fewer tunnels.

Figure 10: Baking results of muffins baked with eGdL/$NaHCO_3$ or $KHCO_3$ versus SAPP28/$NaHCO_3$ (reference)

a) Top view

SAPP28/$NaHCO_3$ | eGdL 80%/$NaHCO_3$ | eGdL 80%/$KHCO_3$

SAPP28/$NaHCO_3$ | eGdL 80%/$NaHCO_3$ | eGdL 80%/$KHCO_3$

b) Cross section

SAPP/$NaHCO_3$ | eGdL 80%/$NaHCO_3$ | eGdL 80%/$KHCO_3$

GdL/$KHCO_3$ | eGdL 85%/$NaHCO_3$ | eGdL 85%/$KHCO_3$

The recommendation for product developers is to use the eGdL80%/$KHCO_3$ combination to reduce sodium and phosphates for a muffin-type product in order to get to a baking result very similar to that with SAPP28/ $NaHCO_3$.

Baking trials scones

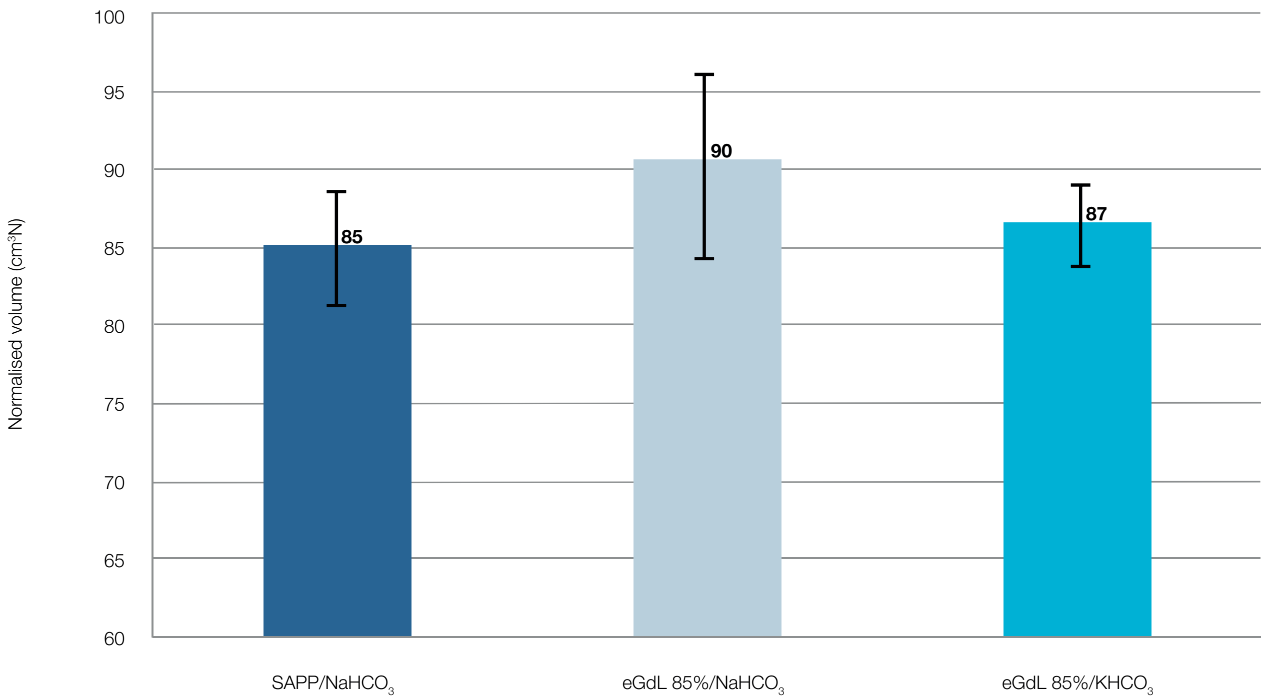
The recipe in table 6 was used for the baking tests with scones. The baking conditions were 218°C (425°F) in a conventional oven for 10–12 minutes.

Table 6: Scone recipe for baking powder combinations with $NaHCO_3$ or $KHCO_3$

Ingredient	Baker's % $NaHCO_3$	Baker's % $KHCO_3$
Flour	100.0	100
Sugar	15.0	15.0
Dextrose	3.5	3.5
Buttermilk powder	2.25	2.25
Baking powder	2.8 – 4.5	3.1 – 4.8
All-purpose shortening	15.0	15.0
Water	60.0	60.0
Salt	1.25	1.25
Total	**199.8 – 201.5**	**200.1 – 201.8**

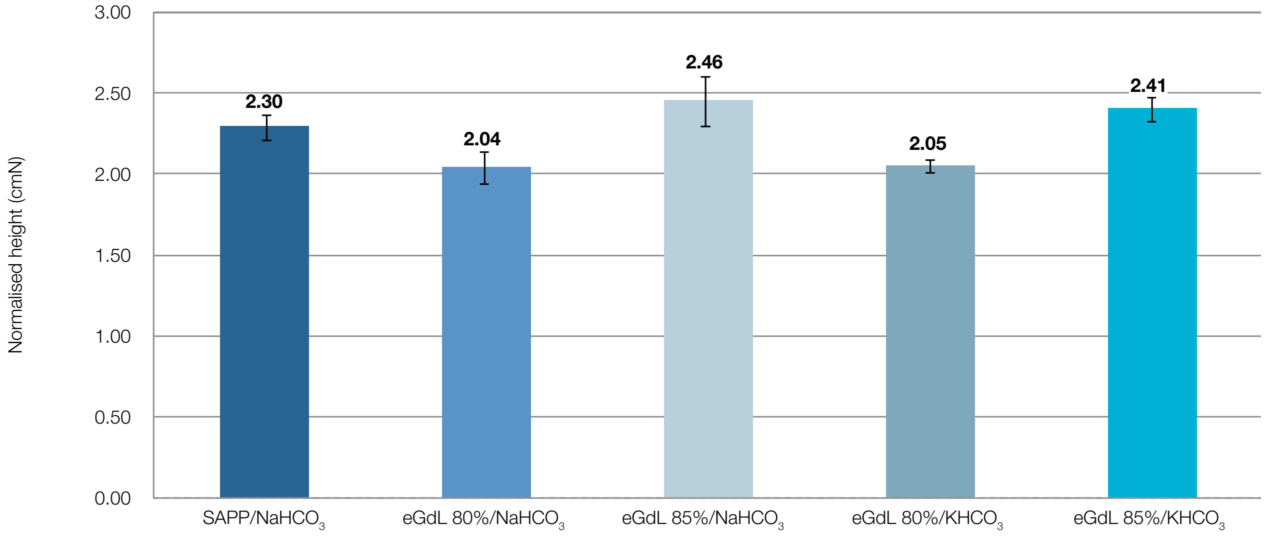
The volume of the scones baked with the baking powder based on eGdL85% was slightly higher for both combinations with $NaHCO_3$ or $KHCO_3$ compared to the reference, although the difference is not statistically significant.

Figure 11: Normalised volume of the scones baked with eGdL85%/$NaHCO_3$ or $KHCO_3$ in comparison with SAPP28/$NaHCO_3$.



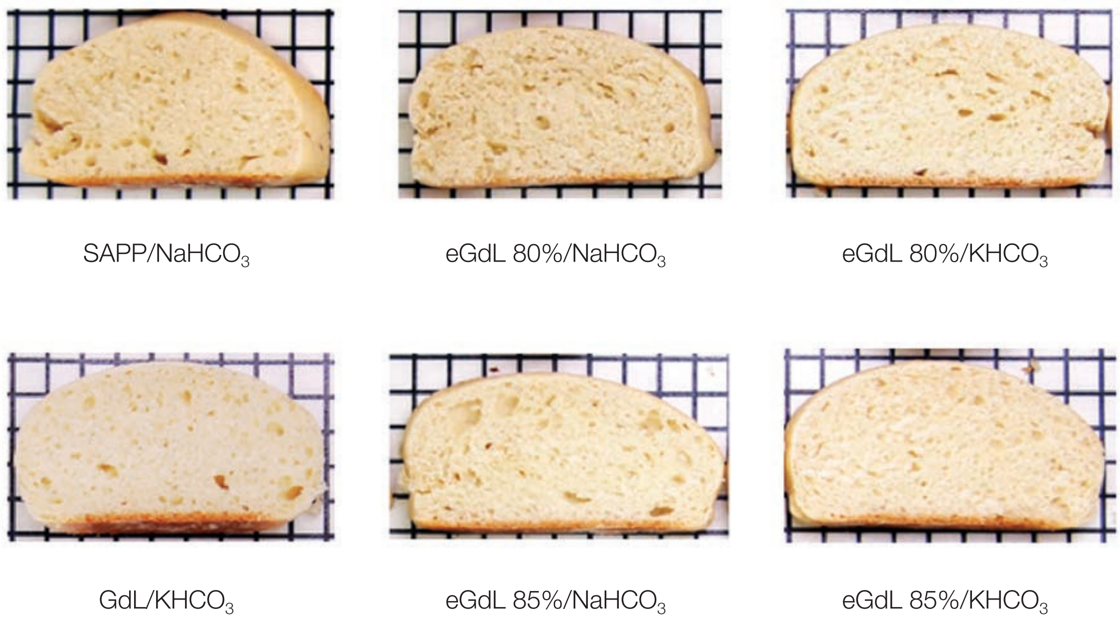
For the height of the scones we see a complementary situation versus the results for the muffins. This time the scones baked with eGdL85% show a height that is superior compared to the reference. The height for the scones baked with eGdL80% remains somewhat lower than the reference.

Figure 12: Normalised height of scones baked with eGdL80% or eGdL85% in combination with $NaHCO_3$ or $KHCO_3$ versus SAPP 28/$NaHCO_3$ (reference)



Pictures of the baked scones are shown below (figure 13). These reveal the height differences between the scones baked with eGdL80% and eGdL85%. The crumb structure looks comparable for all scones.

Figure 13: Cross-section of scones baked with eGdL/$NaHCO_3$ or $KHCO_3$ versus SAPP28/$NaHCO_3$ (reference)

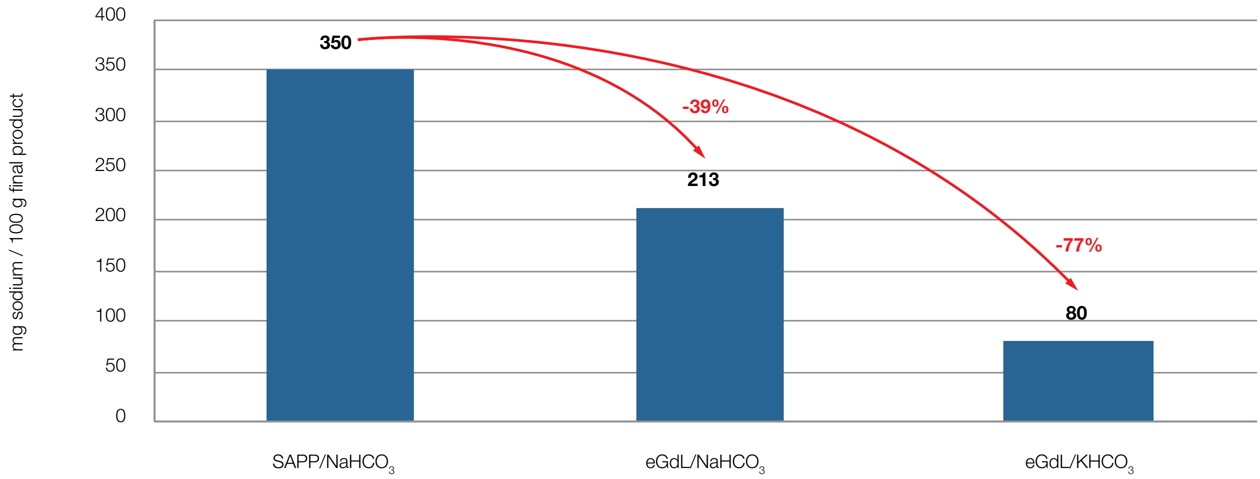


The recommendation would be to use a baking powder combination consisting of eGdL85%/$KHCO_3$ for a sodium-reduced scone product.

Sodium reduction benefits

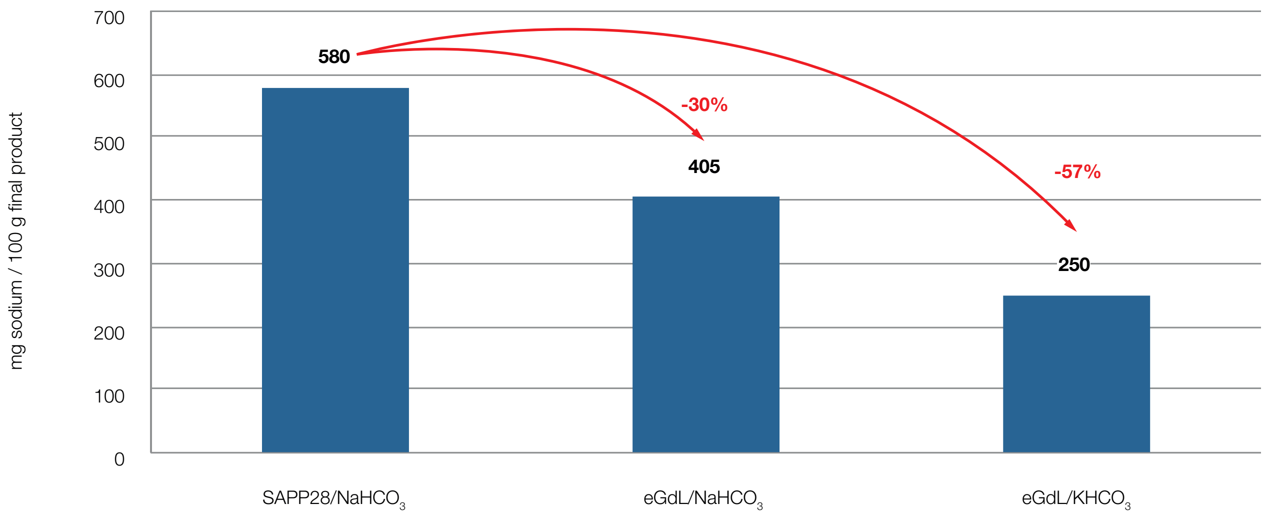
The sodium reduction for the muffin products is summarised below (figure 14). The replacement of SAPP28 with eGdL provides a reduction of more than 35% of sodium content in the final product. However, with the eGdL/$KHCO_3$ combination a remarkable reduction of more than 75% can be achieved. This means that the new limits for sodium reduction published by Public Health England can be achieved by completely replacing sodium-containing baking powder ingredients.

Figure 14: Sodium reduction effect with stepwise replacement of SAPP28 and sodium bicarbonate (sodium content in mg/100 g final product)



The sodium reduction effects for the scones were not as pronounced as for the muffins. However, a reduction of 30% was achieved using an eGdL/$NaHCO_3$ baking powder combination. A full replacement resulted in a sodium reduction of >55% versus the reference.

Figure 15: Sodium reduction effect by stepwise exchange of sodium-containing baking powder ingredients in scones (sodium content in mg/100 g final product)



Summary

Two formulation strategies were pursued to reduce sodium content in chemically leavened bakery products.

In the first, sodium-containing phosphates were replaced by microencapsulated GdL. This achieved a sodium reduction of more than 30% in the final product.

In the second, sodium bicarbonate was additionally replaced by potassium bicarbonate. This step allowed a reduction of between 50% and 80% of overall sodium content in the final product. Even very strict sodium limits (e.g. Public Health England) can be achieved by adopting this strategy.

We developed two types of microencapsulated GdL that can mimic the behaviour of SAPP.

We demonstrated that we were able to overcome stability issues associated with the combination of GdL and potassium bicarbonate by encapsulating the GdL.

There is no drawback in terms of taste associated with sodium-reduced baking powders. On the contrary: when the phosphates are replaced with eGdL the metallic off-taste can be eliminated. Nor does adding potassium bicarbonate to baked goods give rise to any noticeable bitter off-taste.

References

[1] WHO report: Sodium intake for adults and children, 1. Sodium, Dietary. 2. Chronic disease – prevention and control. 3. Guideline. World Health Organisation 2012

[2] Salt Reduction Targets 2017, Public Health England (PHE), No: 2016677, March 2017

[3] Kroning C (2011): Reduce sodium – maintain good taste. Sweat baking, Jan 2011, 20–22

[4] Lubasch K., Siebenrock C, Lenz D, Mason R, (2017) US Patent application, unpublished

[5] Tillmans-Heublein method: The Tillmans-Heublein method uses an airtight glass apparatus to measure the total CO_2 amount by complete decomposition of CO_2-carriers, like bicarbonates, with a strong acid. The CO_2 gas generated displaces a saturated sodium chloride solution. The amount of CO_2 generated can be calculated based on the volume of the sodium chloride solution

[6] Risograph measurement parameters: Water bath at 25.0 °C, manifold of 30.0 °C, measuring time of one hour, measurement setting of 60/1/12 (60 samples per hour/1 sample per minute/12 ports max). Dry ingredients were weighed into reaction vessels, water added and mixed until uniform (~15–20 s), then attached to Risograph and placed into the water bath

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Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Due to continuous investments, state-of-the-art manufacturing processes and comprehensive quality management, we are able to assure outstanding product quality. Our mission "From nature to ingredients®" commits us to the protection of people and their environment.

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