Jungbunzlauer

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facts

Phosphate free raising agents

Introduction

Perhaps surprisingly given its perennial appeal, baking has always involved innovation and development of new products. This applies now more than ever, with food trends such as clean label and demand for healthy and sustainable ingredients ubiquitous throughout the industry. This relates to the leavening acids in baking powder as much as to any ingredient.

Phosphate-based leavening acids have dominated the chemical raising or leavening agents market since the end of the 19th century. In recent years, however, concerns have been raised over the effect on health of excessive phosphate consumption. Studies suggest that high phosphate levels may increase the risk of cardiovascular disease, especially in people with kidney disease.[1-5] High phosphate levels may also increase the risk of adverse effects on bone health in people with a calcium deficit.[6-7] As a result, the EFSA reevaluated phosphoric acid and phosphates as food additives in 2019 and issued a group *acceptable daily intake* of 40 milligrams per kilogram of body weight [mg/kg bw] per day.[8] Other concerns over phosphates relate to their sustainability since they are obtained from minerals and are therefore a finite resource. The phosphate mining process itself also often produces radioactive waste, consumes large amounts of water and releases particulates that can be hazardous to human health and the environment.[9]

Disodium diphosphate, or sodium acid pyrophosphate (SAPP), is frequently used as a leavening acid, particularly in the production of fine bakery products. The production process can be adjusted to control solubility of SAPP molecules, altering the CO_2 release profile, which in turn varies how dough rises over time.

Concerns over health and sustainability have led to a steady increase in demand for non-phosphate alternatives. Unfortunately, the CO_2 release profile of many of the phosphate-free leavening acids currently in use such as cream of tartar often differs markedly from that of phosphate-containing baking acids, with corresponding differences in the finished baked product.

The CO_2 release profile of a leavening system during baking is a crucial parameter since it can have a significant impact on the finished product in terms of height, sensory aspects, texture and appearance. There is as yet no one leavening agent that can be applied universally with the same outcomes for all fine baked products. Some bakery products require rapid release of CO_2 in the dough but lower CO_2 levels during baking, whilst the opposite applies to other products. It is therefore important to use leavening agents that meet the specific requirements for processing baked products. For analytical purposes, CO_2 release in dough can be represented by the rate of reaction (ROR).

This paper by Jungbunzlauer introduces glucono-delta-lactone (GdL), encapsulated glucono-delta-lactone and monosodium citrate as sustainable and biodegradable ingredients which can be used as alternatives to the standard leavening agent SAPP in fine bakery products. It outlines the method developed by Jungbunzlauer to measure the rate of reaction and compares the ROR and baking outcomes for the above ingredients, used singly and in combination, with those of the four SAPP types 10, 15, 28 and 40.

Jungbunzlauer ingredients

Glucono-delta-lactone (GdL), the anhydrous form of natural occurring gluconic acid, is well known as a leavening acid and is frequently used in the bakery industry. GdL by Jungbunzlauer is produced by fermentation and is characterised by its uniquely mild taste and its ability to modulate reaction rate by temperature. One disadvantage of GdL is that it may react prematurely with a CO_2 source such as sodium bicarbonate when stored in the presence of moisture.

One solution to this problem is to encapsulate glucono-delta-lactone. Over the last few years Jungbunzlauer has developed three encapsulated types of GdL (eGdL) based on different coating technologies and processes. All three types are manufactured by granulating GdL to form a powder (F2500) which is then coated with a sunflower oil-based fat (hydrogenated). Encapsulated GdL type S280 H is produced using a drum coating process and contains 80% GdL and 20% sunflower oil whereas eGdL S280 T and S290 T grades are produced using a total coating process and contain 80% GdL and 20% sunflower oil (S280) and 90% GdL and 10% sunflower oil (S290). Total coating is a more specialised process that produces a denser, more uniform and thus higher quality coating.

The major advantage of this physical fat barrier is that it prevents a premature reaction between GdL and bicarbonates. The reaction is not initiated until the fat melts at approximately 71°C (160°F), bringing the individual ingredients of the baking powder into contact with each other. Encapsulating GdL not only extends the shelf life of premixes but is also beneficial over prolonged dough holding times.

Jungbunzlauer's leavening systems also include monosodium citrate (MSC), a monobasic salt of citric acid, which is also produced by fermentation.

MSC is a salt obtained by partial neutralisation and as such occupies a position midway between citric acid and a neutralised citrate. It is available as a spray dried version (MSC D) and a crystallised, granular version (MSC F3500). MSC is used in baked products when a fast-acting leavening acid is required.

All the above ingredients are permitted ingredients widely accepted in the bakery industry and can be used under the *quantum satis* principle.

Rate of Reaction (ROR)

Challenges in developing methods for assessing leavening agents

A variety of methods have been developed over decades for measuring yeast activity in doughs and assessing the performance of baking powder.[10] The CO_2 release profile is a crucial factor affecting the quality and characteristics of baked products, making it a key quality parameter for the various leavening systems.

The Chittick method, raising power probe (RPP), dough rate of reaction (DRR) or rate of reaction (ROR) are methods that are often cited in the literature for comparing baking powders or yeast activity.[11]

The dough rate of reaction or rate of reaction refers to the amount of the CO_2 released within eight minutes in a reaction of a defined amount of sodium hydrogen carbonate and acid.[12]

An internal method for detecting CO_2 release of sodium acid pyrophosphate and encapsulated glucono-delta-lactone, GdL and monosodium citrate in model systems was developed based on this principle.

ROR materials and methods

Experimental setup

The internal measurement device (syringe method) consisted of a 250 mL bottle with lid connected by a cannula to a piston syringe. The bottle was fitted with an internal stirrer and placed on a stirring plate operating at 300 revolutions per minute. Measurements were taken at room temperature.

Test method

Dough preparation:

Wheat flour (type 405) was mixed with water (Black Forest, Peterstaler Mineralquellen GmbH, Germany) at a ratio of 1:2 for three minutes with a paddle stirrer until the dough was free of lumps. The dough was then left for one hour to ensure complete hydration.

Baking powder preparation:

One gram of sodium bicarbonate and the relevant acid were premixed thoroughly in a weighing boat and then transferred to a special paper weighing boat. This procedure was followed for each single acid and combinations of acids at a stoichiometric ratio designed to produce the same amount of CO_2 for each baking powder system.

ROR measurement:

The syringe was connected to the cannula and the lid of the bottle. For each measurement, the paper weighing boat was placed in the bottle neck and used to weigh 120 g dough into the bottle. The bottle was then closed and placed on the stirring plate. The paper weighing boat was dropped into the dough when the stirrer was activated. Measurement was initiated as soon as the weighing boat was stirred in and CO_2 volume was recorded per minute for a total of 15 minutes.

Storage test:

The formulations for the storage test were prepared as described in the “Baking powder preparation” section and stored in baking powder sachets for four weeks at 35°C (95°F) at 75% relative humidity. After four weeks, the samples were evaluated by measuring ROR as described above.

ROR results

Results for single acids

In a first step, four different SAPP types (SAPP 40, 28, 15 and 10) were analysed by at least fourfold determination. The results are shown in figure 1.

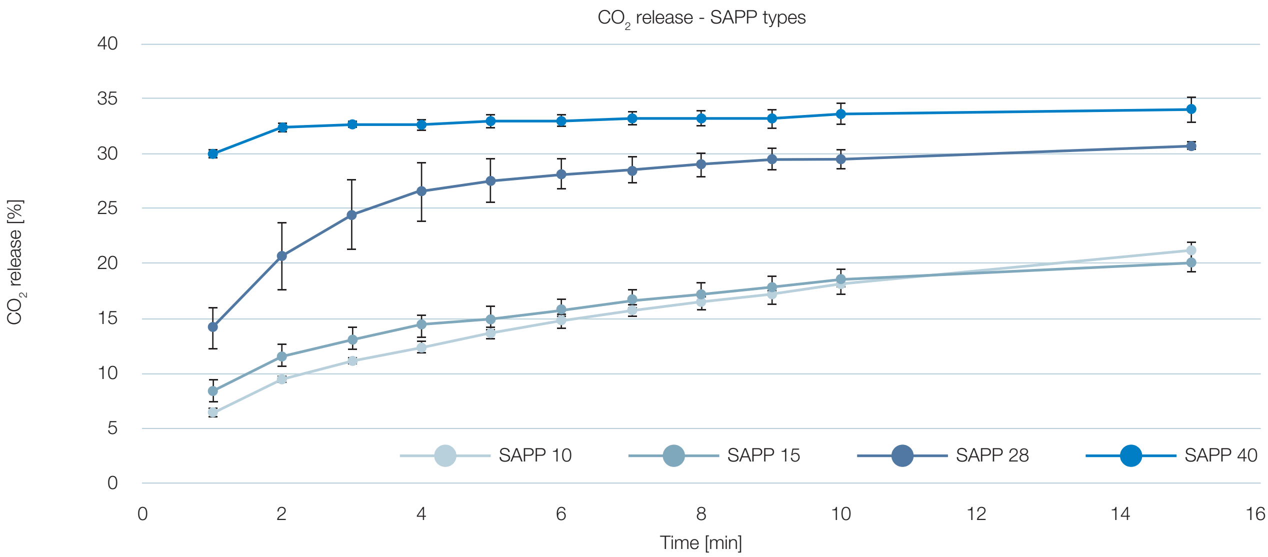

Figure 1: CO_2 release (%) of four different SAPP types.

The graph shows, that the results of the ROR analysis corresponds to the nomenclature of the respective SAPP types described in the literature. ROR, defined as the amount of CO_2 released within eight minutes in a reaction of a defined amount of sodium hydrogen carbonate and acid, is 33.2% CO_2 release for SAPP 40 and 28.9% for SAPP 28. The profiles for SAPP 15 and 10 were very similar with CO_2 release of 17.2% and 16.5% respectively.
In a second step, the CO_2 release profiles of the Jungbunzlauer single acids GdL, eGdL S280 H, S280 T, S290 T, MSC D and MSC F3500 were tested (figure 2).

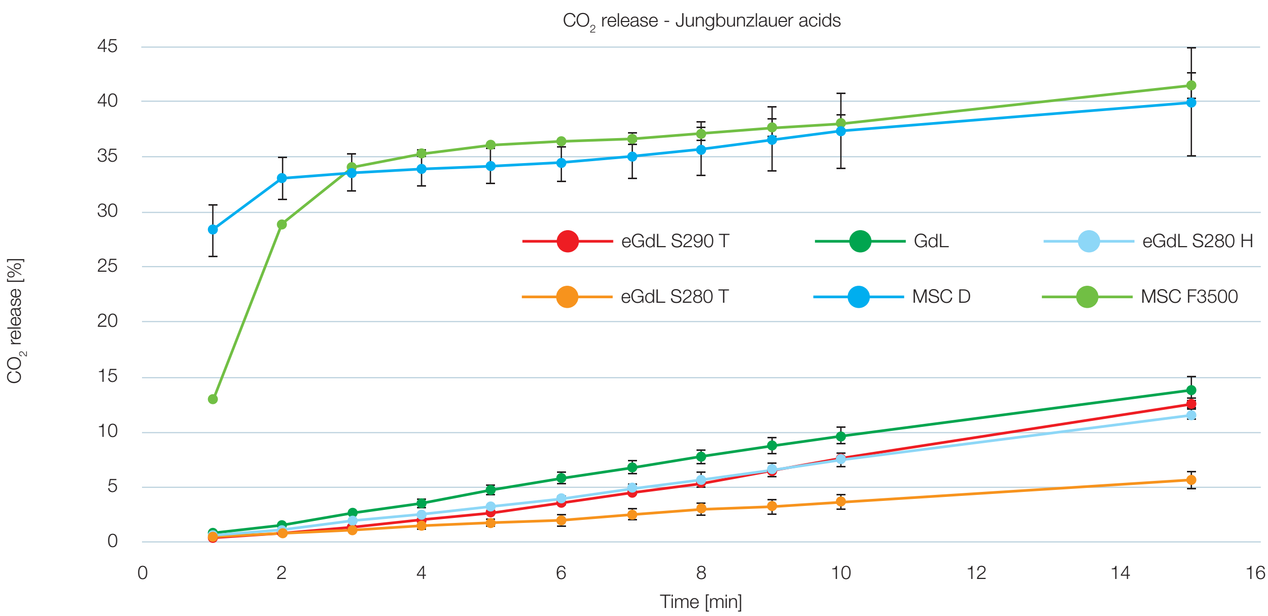

Figure 2: CO_2 release (%) of different Jungbunzlauer acids.

As the above graph shows, there are major variations between the kinetics of the different acids. MSC D and MSC F3500 react very rapidly and release a high proportion of available CO_2 in the first two to three minutes. Compared with MSC, GdL and all the eGdL samples exhibit very slow CO_2 release, up to 10% in the first eight minutes. As expected, uncoated GdL is faster than eGdL due to the lack of coating. Encapsulated GdL S280 H and S290 T shows the same kinetic properties. Encapsulated GdL S280 T exhibits the lowest reaction speed as a result of the thicker and higher quality coating.

Comparison of figures 1 and 2 demonstrates that none of the Jungbunzlauer single acids can mimic the kinetics of any of the SAPP types. Refinement and a modelling approach were therefore required to develop blends of Jungbunzlauer single acids that could match the SAPP kinetics.

Results for match mixes

The SAPP types were reproduced by calculating the CO_2 release rate of SAPP and the equivalent amount of Jungbunzlauer acids applied. Blends of the Jungbunzlauer acids were produced to achieve CO_2 release kinetics matching those of the four types of SAPP ("SAPP match mixes").

Table 1 provides a summary of all the match formulations developed. The quantities of the single acids in the formulations refer to 100 g sodium bicarbonate.

Table 1: Formulations developed to match SAPP kinetics.

	Match SAPP 10	Match SAPP 15	Match SAPP 28 (with GdL)	Match SAPP 28 (with eGdL)	Match SAPP 40
MSC D [g]	25.0	25.0	27.0	26.0	66.0
MSC F3500 [g]		10.0	22.0	27.0	
GdL F2500 [g]			103.2		
eGdL S280 T [g]		157.0			92.0
eGdL S280 H [g]	177.0				
eGdL S290 T [g]				106.2	
Sodium Bicarbonate [g]	100.0	100.0	100.0	100.0	100.0

As shown in figure 3, the kinetics of SAPP 28 and 40 were modelled successfully. Two different match mixes were developed for SAPP 28. The match mix with GdL would be the perfect choice in terms of kinetics but is less stable over storage time, whilst a second version with eGdL (S290 T) has minor deviations in kinetics but better storage stability.

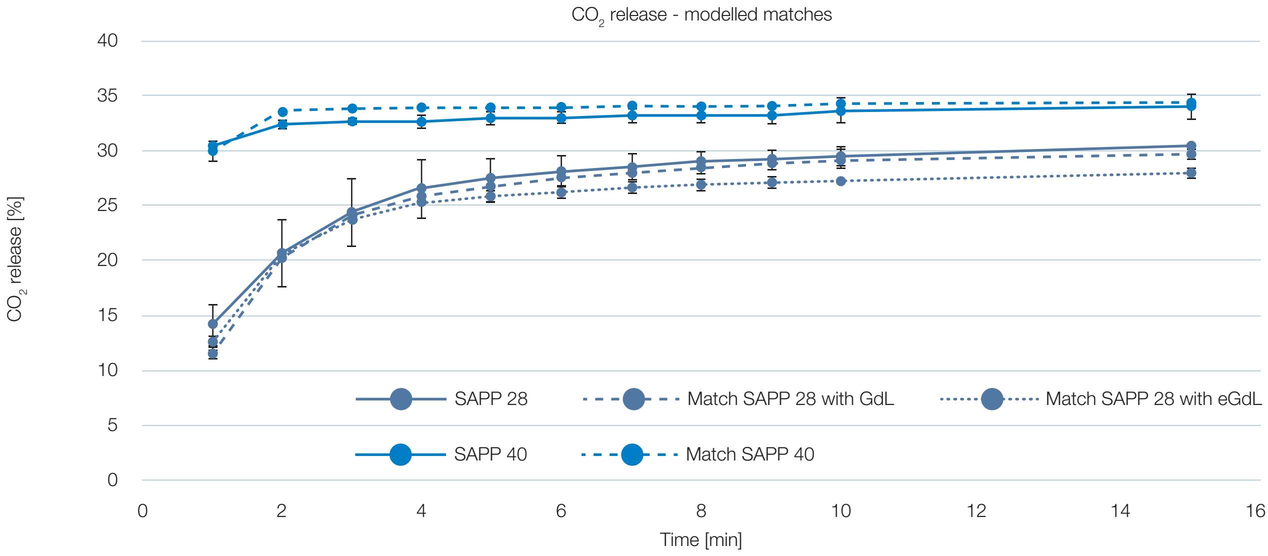

Figure 3: CO_2 release (%) of SAPP 28 and 40 compared to corresponding match mixes.

The graph below (figure 4) shows the CO_2 release of SAPP 10 and 15 and their corresponding match mixes. Slight deviations are visible in the first ten minutes for the SAPP 10 match mix. The match mix for SAPP 15 fits the kinetic profile perfectly up to minute seven but then shows slight deviations in the CO_2 profile. Nevertheless, very good matches were achieved for both SAPP profiles.

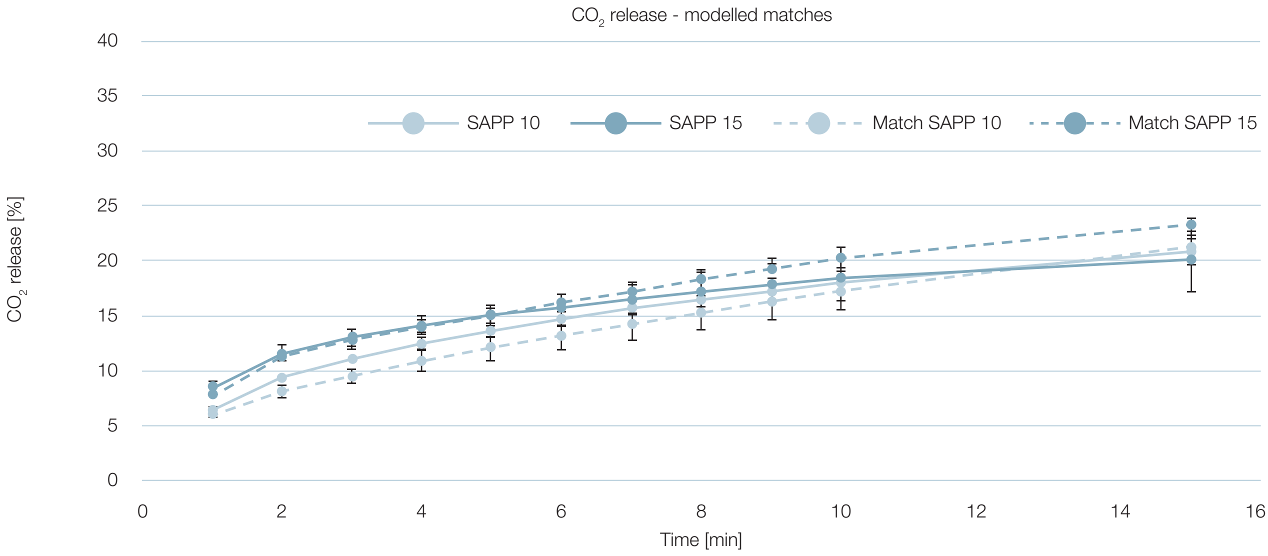

Figure 4: CO_2 release (%) of SAPP 10 and 15 compared to corresponding match mixes.

Results of storage test
After four weeks of storage in sachets, the formulations were analysed using the ROR syringe method and compared to freshly blended samples.

The results confirmed that storage stability of the encapsulated GdL was superior to that of the uncoated acids. All uncoated acids exhibited delayed and reduced CO_2 release when ROR was measured, whilst performance of the encapsulated GdL types remained equal.

A further advantage of the eGdL types is the reduction in caking tendency. As demonstrated in figure 5, the eGdL formulation tends to cake less when compared to its SAPP equivalent. Encapsulated GdL is therefore easier to handle with free flowing behaviour even following storage under harsher conditions.

Figure 5: Formulations after four-week storage test – SAPP 28 (left) and eGdL S280 T (right).

Baking trials

Suitability of the leavening system was verified by conducting baking trials with the above single acids and match mixes to compare their baking performance against the SAPP benchmarks.

Muffin recipe
A standard muffin recipe (table 2) was used to evaluate the baking performance of the different leavening acids. The quantity of each acid applied to the leavening system varies depending on acid stoichiometry.

Table 2: **Muffin recipe for different baking powder combinations.**

Ingredients for 6 muffins	Supplier	%	g
Wheat flour (type 405)		40.5	375.0
Whole egg, dried	Ovodan	2.8	26.3
Skim milk powder		1.2	11.3
Salt		0.2	1.9
Sugar		20.2	187.5
Sodium Bicarbonate	Solvay	0.4	4.05
Acid	**Jungbunzlauer** + various	x	x
Vegetable oil		8.1	75.0
Water		25.5	236.3

The baking trials were conducted with GdL F2500, eGdL S280 H; S280 T; S290 T and MSC D using SAPP 10, 15, 28, 40 as benchmarks. The above-mentioned combinations of Jungbunzlauer ingredients developed to mimic the CO_2 release profile of the four SAPP benchmarks were also included in the trial set-up. A total of 14 different variants of muffin were thus baked, analysed and compared.

5.4 g sodium bicarbonate/500 g flour was used for all baking trials. The equivalent in the Jungbunzlauer muffin recipe is 4.05 g sodium bicarbonate. The amount of acid needed to neutralise this sodium bicarbonate content was calculated stoichiometrically based on the molecular weight of the ingredients. The amount of GdL and eGdL types, was subsequently decreased by 10% to adjust pH.

Experimental set-up of baking trials

The dry ingredients were sieved and scaled into a kitchen machine bowl and mixed for two minutes at medium speed. The liquid ingredients were weighed into a separate kitchen machine bowl and mixed for one minute at medium speed. The mixed dry blend was added to the liquid blend under agitation and the resulting dough was then stirred for precisely three minutes at medium speed. The dough was then portioned (135 g (± 0.1 g)) into greased muffin baking trays. Total dough holding time was 15 minutes consisting of three minutes of dough mixing and a further 12 minutes for dough portioning. The muffins were baked for 35 minutes at 180°C (356°F) with top and bottom heating. The muffins were kept in the trays for five minutes immediately after baking before being transferred to a grate to cool down completely.

Overview of analyses

One day after baking a visual inspection was conducted of the shape, crust and crumb of the muffins. The pH of one muffin per version was then determined using a solid body electrode, followed by volume and height measurement via VolScan Profiler 600 (Stable Micro Systems). The texture attribute "hardness" was determined with a Texture Analyser (Brookfield CT3). Further, the pore distribution of every version was evaluated with an image processing program (ImageJ).

The Jungbunzlauer sensory panel also conducted discrimination tests to determine whether significant differences in taste and texture can be perceived between muffins baked with SAPP 28 and individual Jungbunzlauer single acids or combinations of these acids.

Results of analyses

Appearance and pH
Minor differences between the different versions are visible with respect to shape, crust and crumb. The average pH reading for the various recipes is 7.4 (± 0.2).

Weight
There are no significant differences in weight (< 5%) between the 14 different versions, with an average weight of 117 g (± 2 g).

Height and volume
Out of all the versions evaluated, SAPP 15 muffins exhibit the highest volume and height followed by SAPP 28, with only minor differences (less than 5%) compared to SAPP 15. SAPP types, in descending order by volume and height, are SAPP 15, SAPP 28, SAPP 10 and SAPP 40. Muffins made with MSC D are the smallest with the lowest volume.

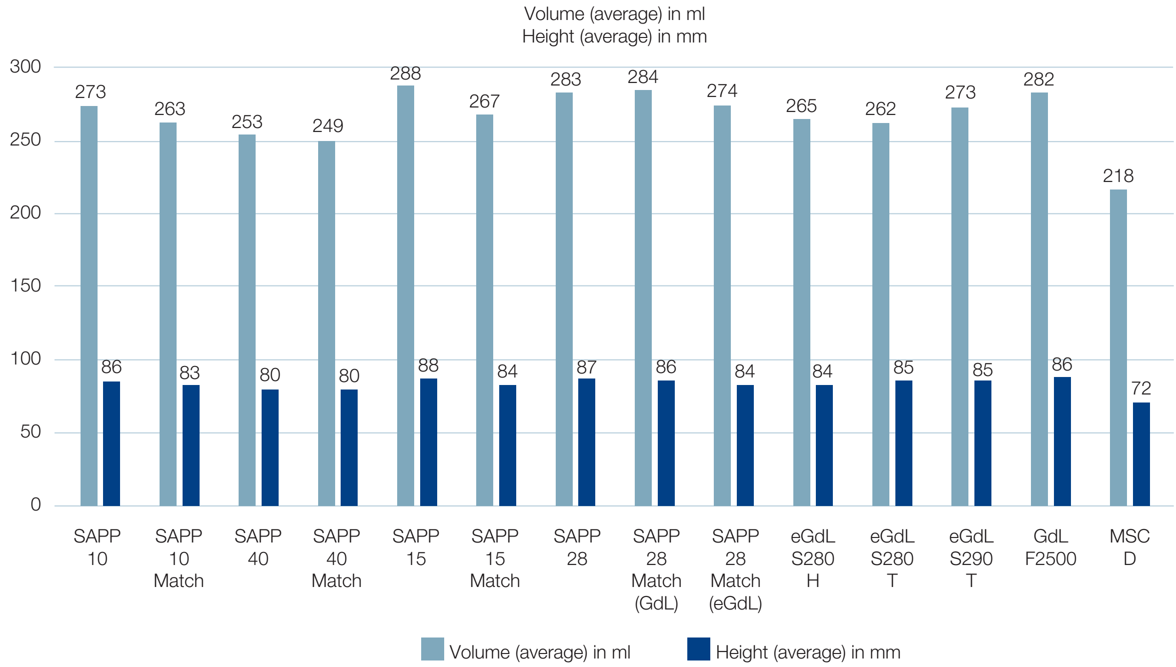

Figure 6: Average volume (ml) and height (mm) of six muffins per version 24 h after baking.

GdL F2500 matches the baking performance of SAPP 28 perfectly and the eGdL S290 T muffin version does not exhibit any significant difference (< 5%) compared to SAPP 28. These results demonstrate that both acids are excellent replacements for SAPP 28 in terms of volume and height. Performance is very similar across all eGdL grades with 20% coating (eGdL S280 H and S280 T) and comparable in terms of height and volume to SAPP 10. Given the similarity in baking performance it can therefore be concluded that the only consideration when choosing coating technology is the intended processing of the baked products.

None of the Jungbunzlauer match mixes differs significantly in volume and height (< 5%) compared to the corresponding SAPP types apart from the Jungbunzlauer match mix for SAPP 15 with a significant decrease in volume (7% less) compared to SAPP 15. SAPP 40, 28 and 10 can therefore be replaced with the respective Jungbunzlauer match mix in a muffin type application without significant differences in baking performance.

Texture analysis

Method

In order to evaluate whether replacement of the leavening acid influences the texture of baked products, the hardness of each muffin version was measured 24 hours after baking with a Texture Analyser (Brookfield CT3). For this purpose, slices from the centre of three muffins of each version were cut into standardised cubes, with a side length of 35 mm and a height of 15 mm, and a Texture Profile Analysis (TPA) was performed.

A fixed cylindrical probe (25.4 mm in diameter) operating at 1.0 mm/s was used to compress the muffin cubes to 30% of their height. The hardness of the sample is defined as the peak force that occurs during compression.

Results

As figure 7 shows, muffins baked using GdL F2500 as leavening acid exhibit the lowest values for hardness (and therefore the softest texture) by a wide margin, followed by muffins made with eGdL S290 T, eGdL S280 H and eGdL S280 T. Thicker coatings appear to increase the hardness of baked products slightly compared to products baked with uncoated GdL. However, all coated acids still produce a softer and therefore, more fluffy structure in comparison to muffins baked with SAPP benchmarks. No significant difference in terms of hardness is observed between the different SAPP types apart from the version using SAPP 40. SAPP 40 clearly produces the hardest texture of all SAPP types in this type of application. The muffin version including MSC D exhibits the hardest structure of all the versions tested by a wide margin.

All of the match mixes show a slight but acceptable increase in hardness compared to the SAPP benchmark versions apart from the match mix used to replace SAPP 40 where, however, the difference is almost negligible.

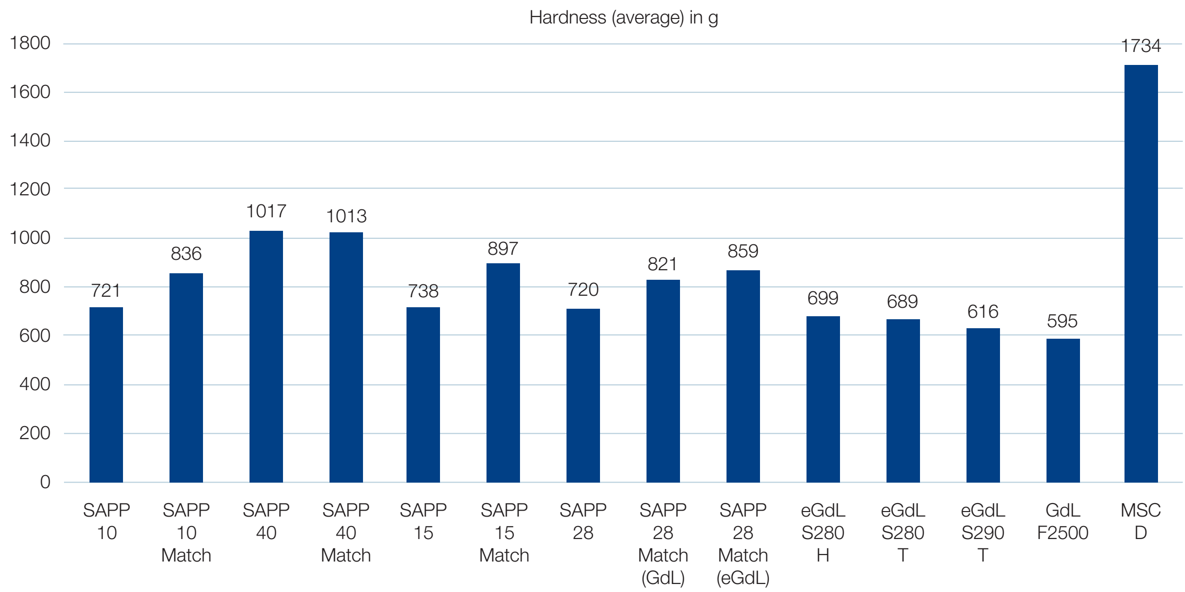

Figure 7: Average hardness (g) of three muffins per version 24 h after baking.

Pore distribution

Method

There is no officially approved method available to analyse and compare the pore size distribution of baked products. Jungbunzlauer addressed this by developing a method using the “ImageJ” image analysis software. In a first step, 12 different pore categories were defined ranging from very fine pores (> 0 ≤ 0.05 cm^2), to very rough pores (> 1 cm^2). In a second step, the software was used to edit images of standardised centre slices cut from muffins. The software then automatically counted the total number of pores and the size of each pore for each slice. Microsoft Excel can be used to calculate the total area of the slice occupied by pores in percentage terms. Total pore area by each of the defined pore categories can also be shown in percentage terms. This method allows the pore structure of the muffin versions to be compared based on the percentage of pore area in each of the defined pore categories. Slices with coarser pores thus exhibit higher quantities of pores in the coarser pore categories.

Results

Out of all the versions analysed, the MSC D muffin exhibits the roughest pore structure by a wide margin. Almost one fifth of the pores was larger than 0.8 cm^2.

Very large pores (≥ 0.8 cm^2) can also be obtained in the versions baked with SAPP 40 and the Jungbunzlauer match mix used to replace SAPP 40. This relatively coarse poring is very typical for SAPP 40 in this kind of application. The pore distribution of SAPP 40 and the Jungbunzlauer replacement turn out to be very similar. Although this is not a desirable pore structure for muffins, the result demonstrates that the baking performance is equal to that of the SAPP 40 benchmark. Pore distribution is also comparable between SAPP 28 and 10 muffins and their corresponding phosphate-free alternatives. It was demonstrated overall that the replacers can mimic the baking performance of the SAPP benchmarks almost perfectly, with only the match mix version used to replace SAPP 15 producing a slightly rougher pore structure than the SAPP 15 version.

A comparison of the pore distribution of muffins baked with uncoated GdL with muffins baked with different coating types revealed that the GdL versions exhibit less total pore area occupied by larger pores than the versions baked with coated GdL. This demonstrates that muffins baked with uncoated GdL have a slightly finer pore structure than muffins baked with coated GdL. Since the muffin version baked with eGdL S290 T exhibits a slightly finer pore distribution than muffins baked with eGdL S280 H and eGdL S280 T, the thicker coating seems to produce slightly coarser pores.

Sensory panel

Sensory evaluation of muffins with SAPP 28 versus different Jungbunzlauer acids

In order to test whether an acid replacement in the leavening system influences the overall taste and texture of the final product, discrimination tests ($\alpha = 0.05$) were conducted using the internal Jungbunzlauer sensory panel.

In a triangle test, panellists are required to identify one sample that is different out of three samples presented. A significant result would lead to the conclusion that replacing the acids of a baking powder system would also have a significant effect on the taste and texture of the baked product.

However, this information alone does not permit a statement about the direction of the difference and therefore about the quality of the product. In order to gather more details, the panellists were asked for comments about the nature of the difference, and which sample they preferred. Although this data is not representative it provides helpful indications with respect to overall acceptance of the different versions.

Sensory test set-up

One day after baking the muffin versions listed in table 3 were presented to the Jungbunzlauer sensory panel (randomised order, blinded with three-digit codes) and analysed in a total of five triangle test sets.

Table 3: Samples for sensory test.

Benchmark SAPP 28 versus	Single acids	GdL F2500
		eGdL S290 T
		eGdL S280 H
	JBL match mixes to replace SAPP 28	SAPP 28 match with GdL
		SAPP 28 match with eGdL

Sensory results – triangle tests

For all five test sets, the majority of the panellists (n = 19–21) were able to differentiate correctly between muffins baked with SAPP 28 and muffins baked with Jungbunzlauer acids.
This indicates that the versions differ significantly from each other ($\alpha = 0.05$) and replacement of the leavening acid in the baking powder system would entail perceptible changes to the taste and texture of the final product.

Sensory results – subsequent preference query
Since significant differences were identified, it was important to clarify whether the difference made was towards an improvement or degradation of taste and texture. The analysis therefore included comments in addition to the results of subsequent preference tests with the panellists who had been able to differentiate correctly between the versions. In each comparison, the panellists clearly preferred the muffins baked with Jungbunzlauer acids over the versions baked with SAPP 28. The only version that was not clearly preferred over the SAPP 28 version was the one baked with eGdL S290 T. In this case there was a balance between panellists with preferences in favour of eGdL S290 T and SAPP 28.

Table 4: Summary of comments from sensory analysis.

Leavening acid used in muffin recipe		
SAPP 28	GdL F2500 eGdL S280 H SAPP 28 match with GdL SAPP 28 match with eGdL	eGdL S290 T
- drier - more compact, less fluffy - more stale and chewy	- more fluffy and soft - less dry - more fresh and juicy	- better overall impression - improved texture: fluffy, soft, fresh

Comments and preference query indicate an overall improvement, especially in texture, with Jungbunzlauer ingredients compared to SAPP.

Summary

Data from the most common SAPP types (SAPP 10, 15, 28 and 40) were compared with the phosphate-free Jungbunzlauer acids glucono-delta-lactone, eGdL S280 H, S280 T, S290 T and monosodium citrate in terms of CO_2 release during the first eight minutes (rate of reaction) and during baking.

In order to visualise the rate of reaction, Jungbunzlauer developed a suitable and reproducible method to measure the CO_2 release and kinetics of the various leavening systems. Results have shown that the ROR profiles of the Jungbunzlauer single ingredients differ from the four benchmarks.

The internal ROR method was therefore used to develop and verify five combinations of the above-mentioned Jungbunzlauer ingredients that accurately resemble the CO_2 release kinetics of the most common SAPP types and additionally exhibit improved storage stability in terms of caking.

The suitability of the different leavening acid systems was verified in baking tests with muffins. The single acids as well as the combinations developed as described above were applied in a muffin recipe and compared to the four SAPP benchmarks. Results have shown that SAPP 28 can be replaced in the formulation by either GdL F2500, eGdL S290 T or the two match mixes developed as SAPP 28 replacements without compromising baking performance. This applies equally whether SAPP 10 is replaced by the corresponding match mix or simply by eGdL S280 H or eGdL S280 T respectively. Similarly, replacing SAPP 40 with the developed SAPP 40 match mix produces comparable baking results. The developed match mix for SAPP 15 is also a well-working phosphate-free alternative to the benchmark, although some slight differences were observed.

Further, the sensory analysis in replacing SAPP 28 in the test formulation demonstrated that either the Jungbunzlauer single acids GdL F2500, eGdL S290 T, eGdL S280 H or the corresponding match mix have a positive effect not only on the taste but also the texture of the baked product.

Performance and use of leavening systems are highly dependent on the specific application and production process and the baking powder system needs to be individually adjusted to reflect process conditions.
All the results provided above demonstrate that Jungbunzlauer has developed outstanding, phosphate-free, sustainable and biodegradable alternatives to the most common SAPP types.

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About Jungbunzlauer

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. Thanks to continuous investment, state-of-the-art manufacturing processes and comprehensive quality management, we are able to provide outstanding product quality.

Our mission "From nature to ingredients®" commits us to protecting people and their environment.

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