BAKING POWDER AND SELF-RISING FLOUR (1) IN NINETEENTH-CENTURY BRITAIN: THE CARBON DIOXIDE AERATIONS OF HENRY JONES AND ALFRED BIRD

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Introduction

It is not known when or how the first leavened bread occurred. The first records are found in ancient Egyptian hieroglyphics and it is possible that the leavening of dough by a fermentation process was known to ancient civilizations long before recorded history.

Baking powder (hereafter BP) is a chemical raising agent used in baked goods. This article will show that its composition has origins from the early nineteenth century when the reaction of an acid with a base to produce a salt plus water and carbon dioxide was the main basis on which developments centered. While BP can be composed of a number of materials, it was commonly, in its early years, baking soda (sodium bicarbonate, $NaHCO_3$) as the alkaline constituent, and cream of tartar (potassium bitartrate) as the acid, diluted with filler such as corn-starch.

Also considered in this article is the early history of self-rising flour (hereafter SRF) but it should be noted that the chemical development of the aerating materials required in this product had a direct relationship with the early BP history: the two products are therefore intertwined. A full historical treatment of SRF must encompass the invention and development of BP since the former product is nothing more than flour to which BP has been added in correct amount. Indeed it can be supposed that the invention of one or other product would in itself lead to the development of the other. In this account only two years separated two main case studies, one of BP, the other of SRF.

Two important protagonists involved in this account are Alfred Bird (bap. 1811-1878) and Henry J. Jones (1812-1891). Both depended on the principal chemical reaction of BP because SRF, as already stated, is merely flour containing BP. Whichever product is under consideration both involve flour containing sodium bicarbonate and an acidic ingredient able to react when in a moist dough to produce carbon dioxide (hereafter CO_2) as aerating agent. The process does not involve yeast fermentation and early BPs were sometimes termed yeast substitutes.

The American history of BP development is well described in Paul R. Jones's paper of 1993 (2). This author points out that Eben N. Horsford began experiments to find a substitute for tartaric acid in the 1850s. This was a period sometime *after* the discoveries and developments of Bird and Jones in England and other earlier British experimenters. Jones answers his own question as to the inventor of BP, if indeed any one individual holds that distinction, by quoting Justus von Liebig's own words (3):

> …the preparation of baking powder by Professor Horsford in Cambridge in North America, I consider one of the most important and beneficial discoveries that has been made in the last decade.

No comparable assessment of the earlier British development of BP has so far been made and it is hoped that this present article may go some way to remedy this lacuna.

The British story of SRF is not without reliable primary source evidence (4), and it is this that forms the basis of what is known about Jones's endeavors to successfully produce what was the first SRF. Priority of invention will be considered and if this is judged on the basis of who first produced, patented and sold such a product, then Jones will be seen as satisfying these requirements. Nevertheless Alfred Bird produced BP two years earlier in 1843 (5), but apparently without the protection of patenting.

One may ask how these inventors and other early producers of chemical aeration knew about the reaction of fairly innocuous acids such as tartaric and cream of tartar with sodium bicarbonate in order to produce CO_2. An attempt to answer this question is made in this article. To modern eyes, knowledge of BP is in itself sufficient to be able to produce SRF, but perhaps for Jones the idea of a domestic "convenience food" had not occurred, certainly it was not a question addressed by Bird.

The background of Bird and Jones and the chemistry involved in their products will be considered since their success hinged upon the proper working of a chemical reaction dependent upon the correct quantities of materials used. Was it obvious to Jones and Bird that so many ounces of bicarbonate react to neutrality with so many ounces of acid ingredient, whether it is tartaric acid or cream of tartar? The earlier use of dilute hydrochloric acid posed the same question. Unlike the legislative controls regarding bread (6), Jones's and Bird's chemically aerated products continued in production for the following hundred years without serious legislative intervention. Indeed it was not until wartime conditions of the early 1940s that standards were prescribed regarding the available CO_2 content of SRF and BP.

Alkaline and Acidic Constituents

It seems impossible to point to a particular time when sodium carbonate (or bicarbonate) was first found to react with some other acidic ingredient, such as lactic acid in sour milk, as a means of producing CO_2 in a baking process. Such a discovery was very probably accidental as also in the case of potash (or pearl ash) which predated the sodium salts.

Alkaline Constituents

Sodium bicarbonate appears as the most common alkaline substance used in both BP and SRF. Nevertheless, potash (potassium carbonate) played an important part as forerunner to sodium bicarbonate. For example, one early American recipe book of 1796 showed clear evidence of the use of potash, as pearl ash, in domestic baking (7), but ultimately sodium bicarbonate became available from apothecaries and newly developing chemical manufacturers described below. Sodium bicarbonate has retained its position for nearly two centuries perhaps because of its relative cheapness, purity and ability to produce a substantial volume of CO_2. The full chemical nature and understanding arose from the work of Valetin Rose (junior) and S. F. Hermbstädt in the first decade of the nineteenth century (8). Sodium bicarbonate is less alkaline than ordinary carbonate but on a weight-for-weight basis produces more CO_2 when reacted with an acid. Of course, any unreacted bicarbonate in a baking process breaks down thermally from 50° C onwards to produce CO_2, leaving behind undesirable sodium carbonate.

$$2\ NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

However, when reacted with a suitable acid the bicarbonate provides not only the desired CO_2 but also innocuous products and is therefore an ideal alkaline component. Consequently, the acid constituent of BP and SRF has received most attention.

Acid Constituents

The most commonly used acid ingredient was cream of tartar (known to the early Greeks and Romans as tartar). However, experiments were made using dilute hydrochloric acid, and much earlier, soured milk. The latter found application in early baking recipes though it provided only limited aeration (9).

Cream of tartar was a by-product of fermentation in wine making and in this process the increasing alcohol content caused potassium acid tartrate (cream of tartar), to crystallize out on the side of the fermentation vessel. The hard crust, referred to as argol or lees, when refined, became the principal source of cream of tartar. By heating this deposit with a solution of calcium hydroxide, calcium tartrate forms as a precipitate, which by treatment with sulfuric acid produces a combination of calcium sulfate and tartaric acid (dihydroxy-succinic acid). After separation, the tartaric acid can be purified for commercial use.

Following the discovery and preparation of tartaric acid by C. W. Scheele in 1770, its production was soon taken up by apothecaries and small-scale chemical producers. For example, a company at Ternes near Paris owned by J. A. Chaptal (1756-1832) was producing tartaric acid as early as 1804 (10). Instructions for making this chemical by a simple and cheap process also appeared in 1807 (11). Its production in wine making locations was therefore not unexpected; for example, a company set up by Philippe-Charles Kestner (1776-1846) at Thann in the Alsace region produced tartaric acid on a commercial scale as early as 1809 (12). Evidence of much earlier availability of cream of tartar in Britain appeared in a list of materials sold by Bevan around 1730 (13).

Being chemically related, tartaric acid and cream of tartar found use as acidic ingredients:

$$H_6C_4O_6 \text{ (tartaric acid)} + 2\ NaHCO_3 \rightarrow Na_2H_4C_4O_6 + 2\ H_2O + 2\ CO_2$$

$$KH_5C_4O_6 \text{ (cream of tartar)} + NaHCO_3 \rightarrow NaKH_4C_4O_6 + H_2O + CO_2$$

These modern equations show reactions with sodium bicarbonate in which tartaric acid has over twice the neutralizing strength of cream of tartar per unit mass. Though this may appear an advantage it necessitates accurate weighing of smaller quantities and also has the disadvantage of reacting more quickly than cream of tartar.

Early Experimenters and Bread Making

It can be reasonably supposed that potash, as a very early known alkali, was used in bread making perhaps as a means of countering the sourness of sourdough and other similar baked goods. Its availability during the eighteenth century was well established and its chemical understanding arose from Edinburgh's enlightened natural philosophers such as Cullen, Black and Francis Home, the latter having given quantitative credence to its use and as a source of fixed air (CO_2). Indeed, Home's method of quantitative analysis, by its effervescence against a standard acid, while hardly of significance to a baker of the time, would nevertheless have given some degree of tacit authority to the use of potash in baking.

Without any form of artificial aeration, whether produced chemically or by fermentation, a baker would hand knead the dough for long periods of time in order to incorporate air. But it was Thomas Henry (1734-1816), in 1785, who attempted to find a theory about the use of yeast. He believed that during fermentation there is a loss of nutritive gluten and sugar, and therefore his experiments might offer an effective substitute for yeast.

He also thought that the gas liberated in fermentation "was the exciting cause, as well as the product of fermentation" (14). Being fully aware of the use of yeast or barm (the frothy substance collected from an already fermenting liquor) in fermentation, he made an experiment in which he introduced CO_2 from an external source into an already fermenting medium. He suspected (15)

> …that fixed air is the efficient cause of fermentation; or, in other words, that the properties of yeast, as a ferment, depend on the fixed air it contains; and that yeast is little else than fixed air, enveloped in the mucilaginous parts of the fermenting liquor.

Whilst this belief is in error it nevertheless reinforced the close connection between fermentation, fixed air, and the aeration of baked goods. Henry described his experiment thus (16):

> I therefore determined to attempt the making of artificial yeast.
>
> For this purpose, I boiled wheat flour and water to the consistence of a thin jelly, and, putting the mixture into the middle part of Nooth's machine, impregnated it with fixed air, of which it imbibed a considerable quantity. The mixture was then put into a bottle, loosely stopped, and placed in a moderate heat.
>
> The next day the mixture was in a state of fermentation, and, by the third day, had acquired so much of the appearance of yeast, that I added to it a proper quantity of flour, kneaded the paste, and after suffering it to stand, during five or six hours, baked it, and the product was bread, tolerably well fermented

However one views Henry's erroneous conclusion, it was nevertheless, commonly held. Indeed, not until the work of Pasteur in 1857 was it realized that fermentation is a biological process, and a further twenty years elapsed before the microorganisms were identified in detail (17).

Henry's 1785 experiments were fully endorsed twenty years later by Abraham Edlin, a physician and surgeon of Uxbridge, who repeated the process and recorded his observations in detail. Edlin took matters further by advocating the use of aerated water in the form of "one pint bottle of the artificial Seltzer water, prepared by Mr. Schweppe, …" (18). He then listed various foreign natural spring waters equally capable of use in fermentation. A note of interest resulting from Henry's and Edlin's suggestion for an external source of CO_2 lies in a later process devised by Dauglish—see below—whose industrial-scale bread making depended entirely on injecting the gas into bread dough.

Edlin's work, and to a lesser extent Henry's, is frequently referred to by Thomas Thomson, MD (1773-1852), in his *System of Chemistry* of 1810. In the chapter "Of the Panary Fermentation," for example, Thomson repeats Edlin's recommendation for the use of potash where otherwise sourness in dough might occur (19):

> It consists in adding a sufficient quantity of carbonate of potash to neutralize the acetic acid, and to knead the alkali rapidly into the dough, so as to prevent, as much as possible, the carbonic acid disengaged, from escaping.

There is no mention however of using sodium carbonate with hydrochloric acid as an alternative to yeast-raised dough.

By 1838 Thomson had slightly revised this section of his *System* and this appeared in *Chemistry of Organic Bodies* (20). Here he reports the use of the sesqui-carbonate of ammonia "to render their bread porous" by the addition of a quarter of an ounce to every pound of flour and that any residual ammonia after baking should be insufficient to cause concern. Somewhat earlier in 1820, Frederick Accum had suggested the use of ammonium bicarbonate in bread making, but there is no evidence of its commercial use (21). Thomson also mentions Colquhoun's method (see below) of using sodium bicarbonate or magnesium carbonate with a solution of tartaric acid. And again, like Colquhoun he noted the difficulty in getting successfully raised ginger bread; a result which could be achieved by incorporating potash. Thomson repeated Colquhoun's suggestion to use "the requisite quantity of sulfuric acid to saturate the alkali" in gingerbread making, but the result often being "a taste decidedly bitter" (22).

Interestingly in 1817, the *Gentleman's Magazine* reported on a substitute for yeast in bread making, quoting from a letter from a reader of *The Monthly Gazette of Health* and the response of its editor (23). The letter, regarding the difficulty of getting bread to rise, asked if "using alum or potass, this desideratum may be accomplished; …"

The editor replied by stating his own practical success in this endeavor by using:

> … four drachms of carbonate of soda … with six pounds of flour … mix three drachms of muriatic acid, diluted with a pint of water … The acid and soda, uniting in the mass, form the culinary salt, and during the union a considerable quantity of fixed air is disengaged …
>
> Salt of tartar and soda, which have been recommended to the public prints to improve bread, render it darker, and so far as the Editor's experience goes, more heavy.

Henry's and Edlin's work was summarized in an essay of 1826 by Hugh Colquhoun (1802-1878) (24). But first he pointed out that the acidity sometimes found in bread by "over-fermentation" (allowing the fermentation by yeast to proceed too far) results in an "acetous" taste which can be easily remedied (25):

> The use of a little of the carbonate of soda, or of the carbonate of magnesia, is all that is required in order to secure to the baker a dough which he may always have sweet and pleasant during the entire progress of fermentation; …

Recognizing that the evolution of CO_2 from added carbonates "materially promote the vesicularity of the bread," he mentions that the use of sesqui-carbonate of ammonia in his own baking tests always resulted in residual ammonia in the bread and poorer texture compared with yeast-raised bread. Whilst acknowledging Edlin as the first to impregnate dough with CO_2, he nevertheless questions his theory that this gas affects the yeast fermentation where (26)

> …the activity of yeast in exciting the saccharine fermentation of dough, resides exclusively in the carbonic acid gas with which that liquid is always nearly saturated, when kept properly excluded from the open air.

In support, Colquhoun quoted M. Vogel as having found only negative results in similar trials. However, convinced by his own tests, Coulquhoun claimed CO_2 as being "incapable of exciting the panary fermentation," having experimented with both sodium carbonate and magnesium carbonate "in those proportions in which they pretty exactly saturated each other, with the requisite quantity of water holding the acid solution" (27). He also tested the use of tartaric acid and magnesium carbonate; in one recipe he quoted "4 ounces flour; 20 grains sesquicarbonate of soda; 19 grains of tartaric acid" and in using magnesium carbonate he quoted "4 ounces flour; 30 grains carbonate of magnesia; 15 grains tartaric acid." In both recipes there was an excess of bicarbonate and thus an insufficient quantity of tartaric acid to generate the full potential amount of CO_2 (28).

But from these and other formulations, he noted the early loss of CO_2, this being more than in standard yeast-raised bread (29):

> … that no loaf-bread can be well made by any of the extemporaneous systems above considered, because they are all inconsistent with the thorough kneading of the dough. It is this process which is found to render dough at once elastic enough to expand when

carbonic acid gas is generated within it, and cohesive enough to confine this gas after it is generated.

Such observations show Colquhoun's very forward thinking on this subject much of which arose from his baking experiments. He also found the use of a mixture of sodium carbonate and tartaric acid proved most acceptable in taste and aeration, particularly in the difficult making of ginger bread. In an interesting footnote Colquhoun pointed out that "tartaric acid may now be purchased at 4s. 6d., and carbonate of magnesia at 1s. 4d. per pound" (30).

It might be reasonably assumed from Colquhoun's reporting that the use of solid aerating ingredients was poised to become accepted practice. Oddly this was not the case, and experimentation in the use of dilute hydrochloric acid continued. Before assessing one particular case that of Whiting, whose approach resulted in his taking a patent based on the use of hydrochloric acid and bicarbonate, we note that other experimenters continued on similar lines.

For example, though somewhat later, in 1846, there appeared an anonymously published pamphlet in which the author, probably George Darling, gave instructions for aeration by using sodium carbonate and muriatic acid (31). The author of this pamphlet claimed that Thomas Thomson wrote an essay on baking for the supplement to the *Encyclopaedia Britannica*, published in 1816, 2nd volume (32). This was said to contain the suggestion to use carbonate of soda with muriatic acid to obtain a better performance than that given by yeast in bread making (33):

> … the dough so formed will rise immediately, fully as much, if not more, than dough mixed with yeast; and when baked, will constitute a very light and excellent bread.

The writer also claimed to having tested out Thomson's instructions using this recipe (34):

> Flour, 3 lbs. avoirdupois, Bicarbonate of Soda, in powder, 9 drachms apoth. weight and Hydro-Chloric acid (Muriatic) 11 ¼ fluid ounces. Sp. Gravity 1.16.

He then pointed out that:

> … the proportion of soda and acid are those which make common culinary salt, when united chemically … If either soda or the acid be in excess, the bread will taste of one or the other accordingly …

The pamphleteer claimed, "It always appeared to us [Darling] that the proportion of hydrochloric acid recommended by Dr. Thomson was too great …" in that 7 oz of hydrochloric acid is too large a quantity for 2 oz of carbonate of soda. Darling proposed therefore a better bread recipe of 3 lb avoirdupois flour, half an oz bicarbonate, 5 fluid drachms of hydrochloric acid of specific gravity 1.17 and 26 fluid oz of water. Nevertheless, this recipe would give a very slight acid result and 0.5% (by weight) available CO_2.

In the same year (1846), the editor of the *Edinburgh Medical and Surgical Journal* reviewed and excerpted this pamphlet under "Materia Medica and Therapeutics" (35), pointing to the tract's support of "unyeasted bread" as being "more salubrious and more safe for the dyspeptic." Also advocating the consumption of unfermented brown bread to "obviate constipation and to diminish the violence of dyspeptic symptoms, … (36)."

The idea of using an external CO_2 source however did not end with Henry or Edlin, for somewhat later (in 1860) the physician and bread maker, John Dauglish, MD (1824-1866) (37), perfected the use of a solution of carbonic acid but in which the kneading process was carried out in a pressurized vessel thus restricting premature loss of CO_2 from the dough (38). According to Burnett, Dauglish's work ultimately led to the formation of The Aerated Bread Company (39), and mechanization of the baking industry.

Nevertheless, the internal chemical generation of CO_2 remained a desirable objective and so, even without knowledge of the work of Henry, Thomson, Colquhoun *et al*. it remained possible that early bakers found by accident that addition of potash altered the taste and aided aeration of the dough—by its reaction with natural acids of the dough or other acidic ingredients to evolve CO_2. And so from these early steps in the development of chemically and physically generated CO_2 significant changes in baking practices became possible.

John Whiting: An Early Patent for Unfermented Bread

Firm evidence of an acid alkali reaction being used as a means of creating satisfactory dough is seen in the patent of John Whiting of Kennington in 1836 (40). In this Dr. Whiting chose to use hydrochloric acid as the acid ingredient but its use was not original as is evident by the earlier work described above. Also, a somewhat later comment by Andrew Ure is noteworthy (41):

> … when a dough containing sesqui-carbonate of soda is mixed with one containing muriatic acid, in due proportions to form the just dose of culinary salt [neutrality], the gas escapes during the necessary

> incorporation of the two, and the bread formed from it is dense and hard. Dr. Whiting has, however, made this old chemical process the subject of a new patent for baking bread.

Indeed, Ure's criticism also included the work of Colquhoun and Edlin by stating that chemically raised bread (including the use of ammonium bicarbonate) remained inferior to that raised by conventional yeast fermentation:

> … a proper spongy bread cannot be made by the agency of either carbonic acid water, or of mixtures of sesqui-carbonate of soda, and tartaric acid.

Nevertheless, the use of muriatic acid proved of value in baking and is strikingly given in Whiting's patent of 1836.

The Patent

The main body of the patent claims (42):

> … to consist in preparing such food by means of an acid and an alkali (such alkali being in union with carbonic acid), whereby the same is rendered cellular light (spongy), without the aid of fermentation. The acid I employ in the manufacture of bread is the muriatic acid (called also hydrochloric acid, and spirits of salt), and the alkali is the carbonate of soda, or what is considered to be by chemists a sesquicarbonate or bicarbonate. When these two articles, namely, the muriatic acid and carbonate of soda, are mixed together in proper proportions, the following changes take place: namely, two of the ingredients which they contain, combine to form common salt, two other ingredients combine to form water, while the carbonic acid is separated in the form of gas, and accomplishes all the duties performed by the carbonic acid extricated during the common fermentative process of making bread (which fermentative process I consider to be prejudicial), whether produced by permitting the dough, by standing and heat, to rise by fermentation, the result of spontaneous decomposition, or by aiding such fermentation by yeast, as is the common practice, or by any other ferment.

Here follows the composition or recipe for Whiting's bread:

> To form seven pounds of wheaten flour or meal into bread, mix from 350 to 500 grains of carbonate of soda above mentioned with about two pints and three quarters of pure water (the quantity of the alkali may be made to vary within the limits above mentioned, as the baker finds it suit best, and depending on the degree of lightness required). Mix with three quarters of a pint of water in a separate vessel so much of pure muriatic acid as will neutralize the quantity of the carbonate of soda employed, the quantity of the acid varying according to the known specific gravity of the acid, and the quantity of the soda in the carbonate, which are subjects familiar to chemists, from about 420 to 560 grains of the acid, as met with in commerce, I have found in practice to be required for 350 grains of carbonate of soda; and I would remark as bakers are not usually acquainted with chemistry, in order to their adjusting the proportions of the muriatic acid and the alkali, they must depend on someone who is possessed of chemical knowledge …
>
> … Let the flour be divided into two equal portions; to one portion thrown into a wide earthenware pan or trough, add the solution of soda gradually, well stirring and beating the mixture with a large wooden spoon, … so as to form a uniform batter … Upon this batter throw the other portion of flour, and while briskly stirring them together from the bottom, pour in gradually the diluted acid, then let the dough be formed, ..."

After further kneading the dough is shaped and baked. On the subject of reaching a chemically neutral baked product, Whiting remarks:

> … care being taken to obtain the extrication of a sufficient quantity of gas, and to form a neutral mixture of the acid and alkali that is to produce common salt, as above explained.

The patent ends:

> ... But what I do claim, as my improvement or improvements, is the preparing such food by means of an acid and an alkali (such alkali being in union with carbonic acid) whereby the foods are rendered cellular light (spongy), without the aid of fermentation, as above described. —In witness, &c.
>
> Enrolled November 3, 1836.

Because of the practical dangers of using hydrochloric acid in this manner one might assume that the idea had a short life; nevertheless, the method remained noteworthy and appeared thirty-six years later in *Chemistry and Chemical Analysis*. This author considered such bread as wholesome as that made with yeast and in order to achieve neutrality in the baked goods (43):

> The amount of dilute acid, required to liberate the gas, may be ascertained, by adding it gradually until effervescence is no longer produced; …

In 1860 Muspratt also reported on the use of bicarbonate of soda with hydrochloric acid (44).

Commentary on Whiting's Method

The first patented method of producing CO_2 in baked goods by reacting an acid with sodium bicarbonate therefore lies with Whiting. The actual chemical reaction was known before 1836 and is today represented thus:

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

This shows neutral residue products of common salt, water and evolved CO_2 provided the reactants are in proper stoichiometric proportion. The patent suggests Whiting's appreciation of the immediate reaction that would take place with an aqueous acid by his attempt to retain the maximum amount of CO_2 in the dough by a well-judged mixing procedure. Indeed the fast reaction of this acid may have been the motive to find slower alternatives such as given by solid and less soluble acids. His more serious problem probably lay in gauging the correct amounts of chemical components. Whiting's lower figure of 350 grains of bicarbonate when added to 7 lb of flour would generate only 0.34% of CO_2 while his upper bicarbonate addition to the same amount of flour would produce 0.48% CO_2. Both results are low compared with present day expectations (0.6%).

On the matter of reaching neutrality in the reaction Whiting is vague and though he suggests that between 420 and 560 grains of acid "of commerce" will react with 350 grains of bicarbonate to reach neutrality. This tells us nothing without additional information regarding acid strength. However, he wisely suggests that "they [bakers] must depend on someone possessed of chemical knowledge, ..." (45).

Any small error in measuring the acid for example could have disastrous results both in monetary value and reputation. Laboratory quality controls to guarantee the strength of the acid or to determine the amounts for exact neutrality (a neutral pH in the final baked goods) had yet to come into being. No evidence has been located to suggest that Whiting's method found commercial application although seven years were to pass before the entry of a practical BP by Alfred Bird. It seems unlikely that the method would have appealed to bakers of bread whose reliance upon established yeast fermentation has remained to present times. Unfermented aerated bread has, even to the present, never been the natural home of chemicals although both Jones and Bird foresaw what we would now call a niche market in naval and military situations. The need for chemical aeration may have arisen in small part due to the increasing sophistication of baked goods other than bread. For example, those with generous amounts of eggs, sugar and milk; here, normal fermentation may be completely inhibited. Also the availability of yeast may have been a factor. But Whiting was quite clearly motivated by a medical or health aspect regarding bread (42). Furthermore, his patent's claim lies not so much in the use of an acid with an alkali, "but that the foods are rendered cellular light (spongy), *without* the aid of fermentation."

One disadvantage of Whiting's method may have been the rapid evolution of CO_2 on adding the acid. Indeed, later development of BPs took into account the importance of the solubility of the acid component, its granularity and the strong influence of a protective flour coating—against premature reaction. These, together with the chemistry of the reaction "to go," greatly influenced the later choice of acidic ingredient.

That the acid component received attention elsewhere is shown in an unusual approach made by Thomas Sewell in 1848. Perhaps unaware of Whiting's method he suggested "acidic flour" in a patent of that year; the "acidified flour" being thus made ready for the customer's own incorporation of bicarbonate of soda (46). By using dilute hydrochloric acid in the form of a fine spray added to mechanically agitated flour this inventor proposed to add (47):

> … forty-five ounces avoirdupois weight of hydrochloric acid of sp. Grav. 1.14, which contains about twenty-eight per cent of real acid, are incorporated with each 280 lbs. of flour … and is ready for sale. Thus a preparation of flour is produced ready to be combined with other ingredients mentioned, which will render it suitable to be made into bread without the use of yeast.

The customer was recommended to add 63 grains of sodium bicarbonate to every pound of flour (within five weeks of production) plus sufficient water to make dough (48). A second "self-rising" product by Sewell proposed flour acidification as above and addition of thirty-nine ounces of sodium bicarbonate to 280 lb of prepared flour (49). After mixing and sieving, the mixture was ready for packaging and sale—with a suggested use within four weeks of production. Nowhere does Sewell mention the likely premature loss of CO_2 during storage but nevertheless recognizes the necessity for a short shelf-life. No evidence has been found that the invention gained commercial interest.

Mr. Jones and Mr. Bird

On the 3rd September 1845, Queen Victoria acknowledged a specification for a new food product developed by Mr. Henry Jones, baker, of Broadmead, Bristol (50). In this document Jones described his development as a true invention in the form of "A new preparation of flour for certain purposes."

Two years earlier, in 1843, Alfred Bird of Birmingham had invented (but without the proof given by patenting) "Fermenting Powder," later to be known as BP. Both Jones's and Bird's products contained two reacting chemicals, sodium bicarbonate and tartaric acid, intermixed with a filler such as corn starch, or as in Jones's case ordinary flour. From these two developments arose the potential to produce leavened or raised dough conveniently without the need of yeast.

With this comparison in mind one may conclude that baker Jones's specification was not a true invention although his patented "prepared flour" led to the first commercial production and sale of what later became known as SRF (51).

The need for exact neutrality of the active ingredients was recognized by Jones and perhaps indicated some knowledge of acid-alkali neutralization. The leavening or rising of baked goods was a desideratum usually answered by fermentation but in instances where yeast was not available or was ineffective, a chemical means must also have been desirable. There is ample evidence of Bird's and Jones's early identification of the potential markets for their products in both military and more so in naval outlets. (See below.)

However, the first patented use of tartaric acid and sodium bicarbonate as aerating agents remains with Jones (in 1845), but as already pointed out this can hardly stand as a true invention in the light of the earlier "fermenting powder" of Bird in 1843. Jones's specification merely described the application of the above reacting substances when mixed into excess flour. This is little different from Bird's fermenting powder, only inasmuch as the "new invention" by Jones contained extra filler.

As though aware of Bird's product Jones carefully worded his patent application by explaining that his invention was merely … (52)

> the preparation of the flour itself, in manner aforesaid, whereby it will keep for a long time and be always ready to be made into bread, biscuit, and other like food, without the addition of any fermenting matter…

In other words he did not claim "the invention of making bread, biscuit, or other the like food" but only that of the preparation of the flour. Such were perhaps the meanderings of patents at that time. By preparation of the flour he meant of course the introduction of measured amounts of sodium bicarbonate and tartaric acid in order to generate the aerating CO_2 gas. The term self-raising (or -rising) flour does not appear in Jones's patent and its careful wording may seem unnecessary in that Alfred Bird appears not to have sought similar patent protection. The account given by Turner (5) suggests that Bird's developments arose from his wife's allergy to yeast-raised bread and so "chemically raised" bread seemed a natural step. The *raison d'etre* for the now still famous Bird's Custard seems to have arisen from another allergy of Mrs. Bird, that of eggs in traditional egg custard. It may be that at this time Bird did not see his developments of these products as mere commercial moves—and therefore the value of patenting was not in mind. Nevertheless, advertising became a part of his business strategy as shown in his Worcester Street shop, Birmingham. There he displayed the motto: "Early to bed, Early to rise, Stick to your work, and Advertise."

Although having first formulated his fermenting powder in 1843 it was not until more than ten years later that his public advertising occurred. By this time competitors were beginning to appear as the notices below prove. Jones also gained recognition through local advertising in the *Bristol Evening Post* around 1849 (53). A notice regarding Bird's appreciation of wider markets appeared in the *Illustrated London News* (54):

> Mr. Alfred Bird, chemist, Birmingham, communicated with the Duke of Newcastle, as head of the War Department, offering to supply the troops in the East with his baking and fermenting powder, which would admit of their being regularly supplied with fresh bread, as well as prove invaluable in the hospitals for the supply of the sick and wounded with bread, light cakes, light puddings, and other articles of food suited to their condition.

In due course Bird became successful in supplying BP to Her Majesty's Forces. He appears to have made inroads into naval outlets inasmuch as the following notice appeared in *The Bristol Mercury* (55):

> Alfred Bird's Fermenting and Baking Powder, as approved of by the Lords of the Admiralty, The Secretary of State for War, and the Hon. East-India Company.

Nevertheless, Bird was not without competition in domestic markets, perhaps as a result of the absence

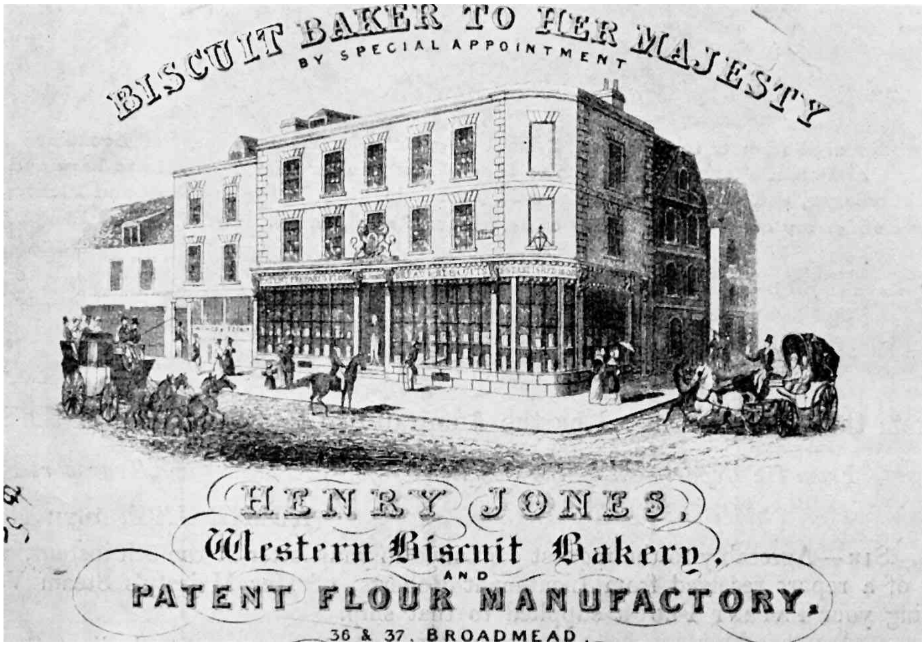

***Figure 1**. The bakery and patent flour factory of Henry Jones, "Biscuit Baker to Her Majesty," in Bristol. Courtesy of Peter Townsend, www.bristolpast.co.uk .*

of patenting. Several new suppliers came into being as shown by newspaper advertising:

- The Bristol Mercury, Saturday, June 6, 1846; Issue 2933 Matthew's Baking Powder "as prepared by E H Matthews of Bristol."
- The Leeds Mercury, Saturday, August 28, 1847; Issue 5934 "Bread Without Yeast—BORWICK'S German Baking Powders On sales at London druggists etc."
- The Times, Thursday, May 3, 1855; issue 22044 "Barm Superseded, by using Bird's Baking and Fermenting Powder" Lists suppliers, e.g., Fortnum & Mason, et al. and Ray, chymist, George street, Dublin ... and of the inventor, Alfred Bird, experimental chymist, 5, Worcester Street, Birmingham.

There is strong evidence pointing to Jones's immediate commercial success. Royal patronage had been granted in 1846, only one year after his invention, by being appointed purveyor of patent flour and biscuits to Queen Victoria. This success and that of the protracted saga with the admiralty is well described by Chivers (56), who provided a generous narrative and ample evidence of Jones's efforts over many years to gain recognition by naval authorities. Such slow progress with these authorities occurred in the face of overwhelming support from individual ships' captains and one important writer to *The Lancet*. An extensive letter by the son of the eminent analytical chemist, W. Herapath, commended Jones's patented flour to mariners and described the product as having "perfectly succeeded in its object" (57). This journal published another correspondent's opinion, "We agree with Dr. Herapath, in considering that Jones's Patent Flour is one of the most valuable inventions of the age; …" (58).

Whatever problems Jones found in his earlier negotiations with the Admiralty there could be no doubt of the efficacy and value of his new product. According to an earlier notice in *The Lancet* (59):

> Approved by the Lords of the Admiralty and eminent Medical and Naval Authorities—By Royal Letters Patent.
>
> Prepared Flour, for making bread at Sea, &c., by the addition of water only. Manufactured by the patentee, Henry Jones, 36 and 37, Broadmead, Bristol. By the use of this flour, captains, passengers to India, &c. may have fresh bread daily through the longest voyage; it is made in two or three minutes, and will be found far superior to that by the ordinary mode. Sold in cases, (containing 14 lb.) 4s 6d …

In the same edition, and others, the following notice appeared:

> Sir, _ With reference to your letter of the 27th ult., relative to your Patent Prepared Flour, from the use of which nautical men may have fresh bread, daily, during long voyages, I have to acquaint you, that

> their Lordships have tried the flour made into bread, which they find to be perfectly good, and wish to know whether your patent can be applied to the flour manufactured in the victualing establishments. I am, sir, your obedient servant, William Leyburn. For Controller of Victualling.

Clearly, not only was Jones an inventor but also a very active business man. By 1846 he had appointed an agent in the West Indies and patents in several other European countries soon followed. Chivers claimed he had "granted licenses to make the flour to seventy-eight persons in Britain, ..." (60). Furthermore, an American patent of 1849 points to Jones's continued commercial success (61).

The question of how an artisan baker became aware of chemical neutrality is not easy to answer, but his patent demonstrates such awareness (62):

> The quantities of acids and alkalies may have to be slightly varied according to their quality, but the point to be attained is the neutralization of both;…

His recipe consisted of 10½ oz tartaric acid, 12 oz sodium bicarbonate, 24 oz salt and 8 oz of loaf sugar, into one hundredweight of flour—these amounts of reactants would give an alkaline result and some yellowing of baked goods, and more importantly, by modern standards a low volume of CO_2 (63).

He gave no indication how he determined the total amount of reactants needed although a later reference to the high cost of using alternative raising agents (potassium bicarbonate, citric acid) suggested he had somehow worked out the minimum quantity to give an acceptable degree of "rise"—if but low by modern standards. To one hundredweight of flour he added the carefully weighed tartaric acid (62):

> I mix it well with the flour, and pass both through a flour dressing machine, and allow it to remain untouched for two or three days that the water of crystallization always more or less present in the tartaric acid may be absorbed by the flour, and so form around the particles of acid a coating of flour that will prevent its immediate contact with the particles of alkali.

Then follows Jones's remarks on two chemical aspects—neutrality and water of crystallization, and perhaps a commercial awareness of sell-by-date aspects of his new food product. Premature loss of CO_2 remained a problem not entirely removed until the introduction of "two stage" reactants based on cream of tartar and later on by acid phosphates. There is no clear indication from where Jones's chemical information came. Chivers mentioned that W. B. Herapath was a personal friend of Jones but sadly gave no direct evidence for this opinion. One indirect pointer to a possible friendship shows in Herapath's letter to the *Lancet* (64):

> Some time ago he [Jones] kindly permitted me to inspect his apparatus and the whole process of preparing the flour, making the dough, and baking the bread … A few minutes suffice to mix the necessary ingredients with the flour, and then, simply by stirring up a little water with this mixture, and kneading the mass for a short time, it becomes a dough, as spongy and elastic as if twelve hours had been consumed in its manufacture by the old method; ...

The writer makes no mention of the nature of the raising ingredients but admits to having eaten a loaf eight months ago and testified "to its sweetness and perfect flavour." Obviously Jones was successfully making unfermented bread long before Herapath's bakery visit mentioned above.

In the absence of appropriate chemical knowledge it seems possible that Jones or indeed Bird, could have based their recipes on simple empirical observation. It should be noted, however, that Jones's home town of Bristol supported a renowned philosophical institution (65) and a Society of Enquirers from 1823 (66). One can reasonably assume these provided areas of active chemical discussion and exchange.

Jones comments on the water of crystallization of tartaric acid but this is not easily understood. His patent implies that the acid would give up its water of crystallization to the flour and so reduce the risk of premature reaction, and also that the flour would provide a protective coating to the acid particles. If he was indeed using a hydrated tartaric acid of say one molecule of water of crystallization, then his final CO_2 evolution would have been further reduced to about 0.31% (by weight). But there is no certainty that a hydrated tartaric acid was in use other than his strange reference to the transfer of water of crystallization to the flour. Muspratt (1860) described Jones's invention without mentioning him by name, and pointed out that the flour mixture should "remain untouched for two or three days, that the constitutional as well as the mechanical water present in the tartaric acid may be absorbed by the flour, …" (67). Water held in hydrated tartaric acid would not tranfer to flour granules. In either case the recipe contains unused bicarbonate due to insufficient tartaric acid which would result in an alkaline baked product. Perhaps his suggestion that the reactants "may have to be slightly

Figure 2. *The patent flour factory of Henry Jones in the 1950s. Courtesy of Peter Townsend, www.bristolpast.co.uk .*

varied according to their quality" was thought sufficient information in a published patent.

Much of Bird's chemical knowledge may have originated from his early apprenticeship with the Birmingham druggists and chemists company of Philip Harris. He became a member of the Pharmaceutical Society of Great Britain in 1842, having set up his own shop in Bell Street, Birmingham in 1837 (68). His life's chemical abilities show in his gaining Fellowship of the Chemical Society on 20th January 1870 (5).

The formulation of a chemical reaction as an alternative to fermentation demanded some moderate chemical knowledge. This would have been well within Bird's capabilities but the expertise of Liebig's more scientific work on the reaction of sodium bicarbonate with an acid to liberate CO_2 in baked goods, did not occur until well after the successes of Jones and Bird in England. Furthermore Liebig should not be entirely credited with the invention of BP as reported by Partington (69). Nevertheless in his *Familiar Letters* Liebig pointed out that during fermentation there is a loss of nutritive value of flour and therefore supported aeration "by means of substances [hydrochloric acid and sodium carbonate] which, when brought into contact, yield carbonic acid." Earlier he had argued differently insofar as (70)

> … chemical preparations ought never, as a general rule, to be recommended by chemists for culinary purposes; since they hardly ever are found pure in ordinary commerce. For example, the commercial crude muriatic acid, which it is recommended to add to the dough along with bicarbonate of soda, ...

Liebig was writing in 1851, but Bird, Jones and others had long before established the better use of solid aerating agents. Whatever uncertainties Liebig's comments suggest, the period of using aqueous mineral acid must have been drawing to a close.

The success of Bird's BP and related products, in parallel with Jones's "prepared flour," later to become known as SRF, is well recorded. Their use of trademarks and packaging gave immediate recognition and show little change to this day. The chemical basis of their products continued to receive investigation—particularly because of the inherent chemical inclination to produce CO_2 prematurely.

While cream of tartar (potassium hydrogen tartrate) was generally the acid ingredient of choice, the investigation of acid calcium phosphate in one form or another soon followed. It was probably Horsford in America, through collaboration with Liebig in Germany who first experimented with phosphoric acid and phosphate salts (71). To this day BPs and SRFs employ acid phosphates offering a two-stage reaction. Tartaric acid, which is very water soluble, is rarely used although cream of tartar remains popular. This, like the acid phosphates, offers slow release of CO_2 in the cold, the main evolution being at oven temperatures (72). Some degree of aeration during initial dough making is desirable followed by further release of CO_2 during proving and final baking. It is in these requirement where acid phosphates (particularly acid sodium pyrophosphate, $Na_2H_2P_2O_7$) prove more favorably but their consideration is outside this present article.

Conclusion

The history of BP and SRF has origins from the early use of pearl ash in baking (for reasons not entirely clear) to the incorporation of a balanced chemical reaction to provide aeration without harmful effect on human digestion. It is perhaps unique inasmuch as it represents a very early employment of a chemical reaction so well known to chemists, i.e. acid plus base gives salt plus water—but in this instance an additional aerating gas, CO_2. From whatever compound an innocuous gas might be easily and cheaply obtained, it was to sodium bicarbonate that early pioneers soon turned, having dismissed potashes, sodium carbonate and ammonium carbonate.

The history therefore turns on the acid rather than the alkaline component. To modern eyes the sheer impracticality and danger of using mineral acids (particularly hydrochloric acid) rules out their use and it is surprising that this means received serious consideration. That such a method continued to be reported in academic journals for such a long period may seem surprising particularly, Muspratt's reporting in1860 of the continuing use of hydrochloric acid in unfermented bread.

In whatever way we now view Whiting's patent and those of others considered in this article, such efforts provided the initial turning point that expanded baking processes.

It is reasonable to assume that the interest in bread by early chemical philosophers, such as Henry in 1785 arose from their medical standing and this article has shown their concerns about yeast-raised baked products. From Henry's early work there appears to have been an idea that in the fermentation process there is a loss of nutritive gluten and sugar. This posed the question whether a more strictly chemical process might overcome this drawback. The possible inconvenience and slowness of yeast fermentation and the market availability of yeast are factors now difficult to determine. If a judgment is on the basis of the number of medical persons investigating this topic, then a perspective embracing nutrition and health seems inescapable. Dyspepsia has been frequently noted as a factor arising from yeast-raised bread and though, to modern eyes, this appears of minor importance it is difficult to judge its contemporary significance. Darling had no hesitation in claiming his process as offering anti-dyspeptic properties and as a means to obviate constipation, but nevertheless the question of taste remained uppermost. Colquhoun had observed the acidity found in bread by over-fermentation resulting in an acetous taste—this being answered by a chemical additive—magnesium carbonate, (a substance frequently prescribed for dyspepsia). But it was his work on chemical aeration which drew Darling's support based on the belief that chemical aeration provided a more "salubrious product ideal for the dyspeptic."

Overlaying these perspectives there nevertheless remained the almost tacit belief that fermentation had some deeper meaning bordering on the mysterious. Oddly, no evidence has been found that the temperance movement (73) ever feared residual alcohol in yeast fermented bread. Nevertheless, according to Harrison (37), Dauglish's competitors were quick to adopt a new selling point for yeast-raised bread "by placarding the neighbourhood of the aërated bread factory with 'Buy the bread with the gin in it.'" But it was also this entrepreneur who firmly believed in the wholesomeness of unfermented bread as against the implicit degradation through "decay and corruption" in fermented bread. However we might now interpret these personal comments it seems clear that medical reasoning provided a motivating force for chemical aeration—perhaps no better illustrated than by Bird's endeavors to remedy his wife's allergies. McGee, in 1984 (74), pointed to an American health movement of the mid-nineteenth century that "raised breads were likely to be harmful," a conclusion apparently reached from certain religious concerns arising from sacrificial ceremonies in which leavening was somehow related to "spoilage and decay."

Although Henry attempted to formulate a theory of yeast fermentation its absence did not apparently hinder his experiments or those of others in finding a chemical alternative to yeast aeration, and by the time of Pasteur's full explanation in about 1857, both BP and SRF were established domestic and commercial products as shown by Bird and Jones.

Priority of invention, whilst of little value in itself, is clearly shown in these two entrepreneurs. Their efforts concerning the aeration of baked goods took different paths, the dates of which preceded developments in America and certainly those of Liebig in Germany to whom credit has sometimes been wrongly directed. The 1840s was a time when industrial revolution in Britain was well under way, population had increased greatly, and bread was needed. It is no surprise therefore that efforts to find an alternative to yeast in bread-making had beginnings before the work of Bird and Jones. The philosophers mentioned earlier devoted their time and text book writings (which often included extensive sections on bread-making), to aeration by chemical means. Concerns were expressed about the quality of chemically raised baked goods (for example, Ure, as shown earlier, made such criticism), but nevertheless Jones and Bird saw beyond this in foreseeing a product ideally suited to the needs of military and naval outlets, almost before similar insight of their commanders (75). To what extent these outlets promoted a domestic demand is impossible to determine. The commercial success of both Bird and Jones, beginning in the 1840s is without question, and SRF has remained to this day a standard domestic product. The fact that baking powder can be used to obtain the same result does not seem to have influenced demand one way or the other. Both products had different origins of motivation—Bird's arose from his wife's allergies and Jones's by mere business drive. Whatever markets these products find in modern day application it should be noted that BP and SRF have retained their role as efficient substitutes to fermentation by yeast.

Acknowledgment

I would like to thank Professor W. H. Brock for his reading of an early draft of this article and the considerable services of the Radcliffe Science Library, Oxford.

References and Notes

1. The term self-rising appears to be more common in US English, self-raising in UK English. —Editor
2. P. R. Jones, "Justus von Liebig, Eben Horsford and the Development of the Baking Powder Industry," *Ambix*, **1993**, *40* (pt. 2, July), 65-74.
3. Ref. 2, p 73, quoting from J. Liebig, "Eine neue Methode der Brodbereitung," *Ann. Chem. Pharm.*, **1869**, *149*, 49-61.
4. Although much of this article draws on patent record information, there is a considerable archive originating from Henry Jones of Bristol, consisting mainly of Letters Patent, licences, and related correspondence held by Bristol Record Office, ref. 29932.
5. J. R. Turner, "Alfred Bird (Bap. 1811, d. 1878)," *Oxford DNB,* Oxford University Press, Oxford, 2004. [http://www.oxforddnb.com/view/article/38977, accessed March 31, 2012]. This author is a great-great grandson of Alfred Bird and the entry is taken from family records and other published confirmatory material.
6. See J. Burnett, "The Baking Industry in the Nineteenth Century," *Bus. Hist.*, **1962-3**, *5*, 98-108.
7. A. Simmons, American Cookery, Hudson & Goodwin, Hartford, CT, 1796, contains four baking recipes where pearl ash is incorporated into milk, cream or water, but no reasons given for its use. Also cited in H. McGee, *On Food and Cooking; the Science and Lore of the Kitchen,* Allen & Unwin, London, 1986 (© 1984), 519. This author claims potash as the first chemical leavening agent, p 533.
8. J. R. Partington, *A History of Chemistry*, Macmillan, London, 1962, Vol. 3, 659 and 579.
9. Though often claimed to be commonly used, the maximum lactic acid content in fully soured milk is rarely much above 1%. On the basis that half a pint (237 mL) of sour milk is needed to produce a dough from 1 lb (454 g) of flour, and assuming all the lactic acid reacted to produce CO_2 from added sodium bicarbonate, the amount of gas produced would be small (0.26%).
10. M. P. Crosland, "Jean Antoine Chaptal," *Complete Dictionary of Scientific Biography*, 2008. [http://www.encyclopedia.com/topic/Jean_Antoine_Chaptal.aspx, accessed Feb. 16, 2013]. See also J. A. Chaptal, *Chemistry Applied to the Arts and Manufactures*, R. Phillips, London, 1807, Vol. 4, 207-209. The author describes a method of preparing cream of tartar from argol or lees which had appeared in *Memoires of the Academy of Paris* as early as 1725.
11. H. Benninga, *A History of Lactic Acid Making*, Kluwer, Dordrecht, Netherlands, 1990, 7, describes a method as given in the first *Dutch Pharmacopoeia,* Bataafse Apotheek, 1807.
12. Ref. 11, p 34, quoting Société industrielle de Mulhouse, *Histoire documentaire de l'industrie de Mulhouse…*, vol. 2, Veuve Bader & Cie, Mulhouse, 1902**.**
13. D. Chapman-Huston and E. C. Cripps, *Through a City Archway: The Story of Allen and Hanburys 1715-1954*, J. Murray, London, 1954, 18.
14. T. Henry, "Experiments and Observations on Ferments and Fermentation; by which a Mode of Exciting Fermentation in Malt Liquors, without the Aid of Yeast, is Pointed out; with an Attempt to Form a New Theory of that Process," *Mem. Lit. Phil. Soc. Manchester,* **1785**, *2*, 257-277 (259).
15. Ref. 14, pp 262-263.
16. Ref. 14, p 263. This is a very early example of impregnating water with CO_2 which, when later released, aids aeration. See also W. V. and K. R. Farrar and E. L Scott, "Thomas Henry (1734-1816)," *Ambix*, **1974**, *20*, 183-208, 204.
17. See K. E. Golden, "Fermentation of Bread," *Bot. Gaz.*, **1890**, *15* (no. 8 August), 204-209. Little was understood of the chemistry involved until the 1880s. It was generally assumed that yeast caused carbon dioxide and alcohol to be generated from sugar: the liberated gas caused the dough to rise and the alcohol was volatilized without residue.

18. A. Edlin, *A Treatise on the Art of Bread-making …*, Wright for Vernor & Hood, London, 1805, 149-151.
19. T. Thomson, *A System of Chemistry*, Bell & Bradfute, Edinburgh, Murray, London, 1810, Vol. 5, 392.
20. T. Thomson, *Chemistry of Organic Bodies: Vegetables*, Bailliére, London, 1838, "Of the Panary Fermentation," 1028-1032.
21. F. Accum, *A Treatise on Adulterations of Food, and Culinary Poisons…* Longman, Hurst, London, 1820, 2nd ed., 125-142, on 133.
22. Ref. 20, p 1032.
23. Quoted in *The Gentleman's Magazine*, 1817, (London), pt. 1, 149 from R. Reece, Ed., *The Monthly Gazette of Health*: a letter from J. O. R., York, Dec. 16, 1816 and the Editor's response.
24. H. Colquhoun, "A Chemical Essay on the Art of Baking Bread," *Ann. Philos.*, **1826**, *12* (New Series), articles I and IV, 161-182, 263-281. The essay was written at the time of his graduation as MD from University of Glasgow. W. Innes Addison, *The Matriculation Albums University of Glasgow from 1728 to 1858*, Maclehose, Glasgow, 1913, 293, shows, "M.D. 1826; never practiced medicine; was partner for many years of firm of Colquhoun & Balloch."
25. Ref. 24 (Colquhoun), p 177.
26. Ref. 24 (Colquhoun), p 265.
27. Ref. 24 (Colquhoun), p 268.
28. Assuming the tartaric acid to be anhydrous in both recipes, the sodium bicarbonate/tartaric acid content would have given about 0.4% CO_2, whilst the magnesium carbonate/tartaric acid about 0.5% CO_2. If neutrality had been reached in these recipes, as the author claimed, the available CO_2 would have been about 0.6% and 0.9% respectively.
29. Ref. 24 (Colquhoun), p 269.
30. Ref. 24 (Colquhoun), p 276.
31. *Instructions for Making Unfermented Bread…by a Physician*, Taylor & Walton, London, 1846. A 15-page brochure, thought to be by George Darling, was issued in several later editions until 1851. A pamphlet is held by Worcester College Library, Oxford. See also J. Dixon, *"George Darling, (1779/80–1862),"* *Oxford DNB*, Oxford University Press, Oxford, 2004, rev. P. Wallis. [http://www.oxforddnb.com/view/article/7154, accessed Apr. 20, 2012].
32. No such edition exists, the nearest next being 1817. No entries regarding the use of muriatic acid with an alkali for aeration purposes have been found in sections on baking, bread, fermentation or in the large chemistry section.
33. Ref. 31 (*Instructions*). This appears on p 4 of the pamphlet, but as stated above no similar instructions by Thomson can be found in the 1817 edition of *Encyclopaedia Britannica* or in Thomson's earlier 1810 edition of A *System of Chemistry*, or in his later 1838 *Chemistry of Organic Bodies: Vegetables*, "Panary Fermentation."
34. Ref. 31 (*Instructions*), p 4. This recipe would result in very acidic baked goods. There is up to seven times more acid present than is needed and the bicarbonate present would give more CO_2 (about 1.3%) than is needed.
35. "Instructions for Making Unfermented Bread, with Observations by a Physician," *Edin. Med. Surg. J.*, **1846**, *66* (pt. 3), 248-250.
36. Ref. 35, p 250.
37. W. J. Harrison, "Dauglish, John, (1824–1866)," *Oxford DNB*, Oxford University Press, Oxford, 2004, rev. C. Clark, [http://www.oxforddnb.com/view/article/7189, accessed Feb. 29, 2012].
38. J. Dauglish, "On a New System of Bread Manufacture," *J. Soc. Arts*, **1860**, *8* (April 27), 414-425.
39. Ref. 6, p 101-102. See also Ref. 37.
40. British Patent no. 7076, 3. Specification of the Patent granted to John Whiting, late of Rodney Buildings, New Kent Road, in the County of Surrey, but now of Kennington, in the said County of Surrey, M. D., for an Improvement or Improvements in preparing certain Farinaceous Food.—Sealed May 3, 1836.
41. A. Ure, *A Dictionary of Arts, Manufactures, and Mines*, Longman, London, 1840, 175.
42. *Repertory of Patent Inventions and other Discoveries and Improvements in Arts, Manufactures and Agriculture. New Series*, **1837**, *8*, J. S. Hodson, London, 1837, 267-271.
43. Commissioners of National Education Ireland, *Chemistry and Chemical Analysis*, A. Tom, Dublin, 1861, 319.
44. J. S. Muspratt, *Chemistry, Theoretical, Practical, and Analytical*, Mackenzie, Glasgow, 1860, Vol. 1, 379, "Unfermented Bread."
45. Ref. 42, p 268.
46. *Repertory of Patent Inventions* … **1848**, *11*, T. R. Sewell, of Carrington, in the Parish of Basford, Nottingham, Chemist, for Improvements in preparing flour. —Sealed January 18, 1848.
47. "On Chemical Substitutes for the Fermentation of Bread," *Pharm. J. Trans.*, **1853-4**, *13* (no.4), 172-174, 173.
48. In baked goods this recipe would result in an alkaline product, there being an excess of added bicarbonate. The quantity of acid in the flour would only neutralize a portion of the added bicarbonate to generate about 0.3-0.4% CO_2.
49. These amounts are similar to those already given and again show an excess of bicarbonate resulting in an alkaline product of poor aeration.
50. British Patent A.D. 1845. No. 10,555, Preparation of Flour. Jones's Specification, 1-3.
51. See D. E. Powell, "Jones, Henry James (1812–1891)," *Oxford DNB*, Oxford University Press, Oxford, 2004. The author describes Jones as the inventor of self-raising flour. [http://www.oxforddnb.com/view/article/74330, accessed Feb. 29 2012]
52. Ref. 50, p 2.
53. See Bristol Record Office, ref. 29932/28/a-b c.1849.
54. *Illustrated London News*, Apr. 24, 1855.
55. *Bristol Mercury*, Feb. 23, 1856, issue 3440.

56. K. Chivers, "Henry Jones Versus the Admiralty," *History Today*, **1960**, *10*, 247–254.
57. W. B. Herapath, "On the Making of Bread without Fermentation," The *Lancet*, **1846,** May 2, 508. See also K. D. Watson, "William Herapath**,** (1796–1868), Analytical Chemist*," Oxford DNB*, Oxford University Press, Oxford, 2004. [http://www.oxforddnb.com/view/article/13011, accessed Feb. 9, 2013.]
58. X., *The Lancet,* **1846,** June 13, 642.
59. Advertisement, *The Lancet*, **1845**, Sept. 13, "Important Inventions," 304. Copy of a Letter from the Board of Admiralty, London: —Admiralty, July 5, 1845.
60. Ref. 56, p 248.
61. H. Jones, "Improvement in the Preparation of Flour for Bread-Making," US Patent 6,418, issued May 1, 1849.
62. Ref. 50, p 2.
63. According to D. W. Kent-Jones and A. J. Amos, *Modern Cereal Chemistry*, Northern Publishing, Liverpool, 1947, (4th ed.), 369, about 3 lb 4 oz of sodium bicarbonate added to 280 lb of flour (1.16%) generates approximately, 0.60% total CO_2 and is regarded as an acceptable amount. Jones used 12 oz of bicarbonate to 112 lb of flour which, by calculation, would only produce 0.35% CO_2, about half of that required by modern standards. In practice the available CO_2 would have been even lower (0.34%) because of insufficient tartaric acid for complete neutralization. He could have safely increased his bicarbonate to 2 1oz, and tartaric acid to 18.8 oz, to give 0.6% CO_2 and a neutral reaction.
64. Ref. 57 (Herapath).
65. Bristol Institution for the Advancement of Science, Literature and the Arts, founded in 1823, and located in Park Street. See M. Neve, "Science in a Commercial City: Bristol, 1820-60," in I. Inkster and J. Morrell, Eds., *Metropolis and Province: Science in British Culture 1780-1850*, Hutchinson, London, 1983, 179-204.
66. Ref. 65, p 192. This Society dates from 1823 and held weekly meetings in the Masonic Hall, Broad Street with William Herapath as a known activist. Frequently reported in the *Bristol Mercury*; no known archives.
67. Ref. 44, vol. 1, 380.
68. Ten years later, in 1852, he passed the Society's major examination and qualified as a pharmaceutical chemist. Registration with the society became a legal requirement to anyone setting up as dispensing chemist from 1868.
69. Ref. 8, vol. 4, (1964), p 316.
70. J. Liebig, *Familiar Letters on Chemistry*, Taylor, Walton & Maberly, London, 1851, Letter XXIX , 443-445.
71. E. N. Horsford, *The Theory and Art of Breadmaking. A New Process Without the Use of Ferment*, Welch, Bigelow, Cambridge, MA, 1861, a 30 page pamphlet. On p 30, the author uses the term self-raising flour.
72. For a full account of this topic see ref. 2, p 67. The use of acid calcium phosphate in England was reported by Horsford in 1868, p 70.
73. A. McAllister to F. G. Page, personal communication, Jan. 17, 2013. The UK temperance movement is generally regarded as having begun in the 1830s and reached its zenith 1870-1900.
74. Ref. 7 (McGee), p 281.
75. Ref. 18. Such outlets had already been identified by Edlin in 1805: "To captains of ships, to military men, and such who travel into unfrequented regions … such plain and easy instructions are laid down for making good bread, …" viii.

About the Author

After retiring from the chemical industry in 1989, the author gained a M.Sc. degree at the Oliver Lodge Laboratory of the University of Liverpool. His studies of early analytical chemistry under the supervision of Professor W. H. Brock resulted in his earning a doctorate from the University of Leicester in 1999. The article above relates from his early employment with Albright & Wilson and involvement with the development of food phosphates.