The theory and art of bread-making. A new process without the use of ferment

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THEORY AND ART OF BREAD-MAKING.

Bread-making, in its widest sense, consists in giving to the flour of certain grains convenient form for the purposes of food. What the form shall be is determined by several considerations, the most important of which is the adaptation of the food to the requirements of digestion. In order to this adaptation, the most essential quality of the bread is surface for the action of the digesting fluids. Bread presenting great surface, so as to yield promptly to the agents of digestion, is healthy, while that which presents little surface, so as to overtask the powers of digestion, as in the case of heavy bread, is not healthy. Surface is gained most conveniently by giving to the mass of flour the cellular structure of raised or light bread. This cellular structure permits the fluids of the mouth and stomach to pass in by capillary action, and by endosmosis and exosmosis to penetrate every part of the mass and accomplish the office of digestion.

As experience has shown wheat to contain the elements of nutritious food in the best proportions for the wants of the human organism, the discussion which follows will be devoted to the art of making bread from wheaten flour. In the broadest acceptation, bread-making might include the preparation of crackers, cake, and all the forms of light and heavy pastry in use; but it is proposed to omit all these, and limit the application of the word bread to the plain, light, or raised wheaten flour loaf, into which, beside the principle of leaven, only salt and water enter as component parts. The great essential process of such bread-making is the production from flour of a permanent cellular structure of convenient size and
form, — to wit, the raised loaf, with but inconsiderable changes of the original flour. If the loaf is made sweet by addition of sugar, or aromatic by addition of flavoring extracts, or rich by addition of eggs or butter or fruit, it is cake or pudding or pastry, but not bread.

Let us consider the material out of which this loaf is to be produced.

Composition of the Wheat-Grain.

Fig. 1.

The crushed grain of wheat is a mixture of reddish-brown and white portions. By bolting or sifting, most of the brown portion is removed. Of this the coarser part is called bran. Bran is commonly though not universally supposed to contain but little of the nutritious part of the wheat. Careful examination shows it to contain much of the interior portion of the berry. The outer true bran, or bark, may be partially removed by moistening the grains and rubbing them lightly between the folds of a coarse towel. This hull or bark so separated is chiefly composed of woody fibre, and contains little nutritious matter. Investigations made elsewhere, and confirmed in my laboratory, have shown the amount of the outer bran that may be so detached to be less than three and a half per cent of the weight of the un-

Fig. 1 exhibits the wheat-grain or kernel of the natural size, presenting the grooved side and reverse, and cross section; also a cross section magnified to 18 diameters, and displaying the bran-coats, gluten-coat, and starch-cells.
branned berry. Within this bark, and constituting a continuous inner wrapper, is the most important constituent of the wheat, as it contains the phosphates and nitrogenous ingredients out of which the digesting and assimilating apparatus elaborate all the important tissues and organs of the body. It is the gluten. Within this envelope of gluten, and extending to the centre of the berry, is a mass of starch. There are then three portions,—the bran proper or outer envelope, the gluten or inner envelope, and the starch.

They are exhibited in Fig. 1. The bark envelope, including also the portion next the gluten, consists of several layers, the outermost of which much resembles very thin straw. The gluten is not fibrous, like the hull or bran proper, but is in cells, and cuts like the rind of cheese. The starch is granular and loosely held together by a coarse network of cellular tissue.

The starch belongs to a class of bodies specially related to the respiratory organs. Its consumption, and that of the gum, sugar, and oil also present in small quantities in wheat-meal, contribute to maintain the temperature of the body necessary to the fulfilment of its various functions.

Gluten is the name under which the chief nitrogenous constituents of the flour are grouped. In it there have been recognized an insoluble portion, the fibrine; a smaller, soluble portion, the albumen; and a portion not so well known, which is said to expedite certain kinds of fermentation, and is called cerealice. As these bodies have substantially the same chemical constitution, it is conceivable that they differ from each other chiefly in the degree of degradation which the latter two have experienced, or in the degree in which they are susceptible of decomposition by the action of ferment, the fibrine being the most stable, and the cerealice the least stable of the group. Besides the gluten in the envelope, there is, according to Mayer,¹ a small amount of a soluble nitrogenous compound distributed throughout the starch.

The gluten and starch may be separated from each other by kneading in a current of water. The former is a tenacious, slightly elastic substance. The latter is granular and loosely coherent.

If a cross section of wheat be exposed for a short time to the action of a solution of ammonio-sulphate of copper, the gluten will be impregnated with a green compound. The extent of the green compound, which is coincident with that of the gluten, will be found to be limited to a thin envelope immediately within the bran proper. If another cross section be exposed for an instant to the action of a solution of iodide of potassium to which a few drops of nitric acid have been added, it will become deep violet wherever the starch granules occur, and the extent of the starch will be found to include the entire space within the thin envelope of gluten. Microscopic examination shows the gluten to be disposed in one continuous layer of cells with no intervening starch granules, and the chemical tests show that the gluten cells penetrate the starch but slightly, if at all.

Fig. 3. Miller’s Bran.

Fig. 2 presents a portion of a transverse section of white wheat, magnified to 150 diameters. 1, 2 are the coats of outer true bran; 2 is the inner coat of true bran; 3 is a thin filmy coat covering the gluten cells; 4, cellulose containing gluten; 5, sacks of gluten; 6, starch-cells.

Fig. 3 is a transverse section of commercial bran, upon the same scale as the last. The layer of starch is sometimes twice or three times as thick as is here exhibited.
Loss of Phosphates with the Bran.

A glance at these figures will explain why Mayer\(^1\) found fourteen times as much phosphoric acid in commercial bran as he found in commercial superfine flour. The bran carried with it most of the layer of gluten in which the phosphates and the companion nitrogenous compounds — the sources of living tissue — are lodged; while the superfine flour consisted chiefly of starch, but little of the gluten having been detached from the bran. Mège-Mouries\(^2\) found the gluten coat to contain ten per cent of nitrogen, while the average of the whole berry is from two to three per cent.

A glance at these figures will also show why the bread made from Graham flour, and the Pumpernickel of Westphalia, which is also made from unbolted meal, and the black bread of like origin found in the sacks of Russian soldiers in the Crimea, are so nutritious, in spite of their heaviness and sourness. They contain all the gluten as well as starch of the grain. All the phosphates and nitrogenous compounds of the grain enter into the bread when the bran is not separated from the flour, instead of a small fraction only, as in bread made from superfine flour.

Fig. 4 exhibits the arrangement of the successive coats, including the gluten and gluten-cells, more or less of each coat being removed, so as to display the order of succession. It is also on a scale of 150 diameters. The coats 1, 1 are readily separated with a moist cloth.\(^3\)

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3. Mr. Thos. J. Hand, of New York, to whom I am indebted for these most detailed and elaborate original drawings, and who has in numerous ways aided
Difficulties of Bread-making.

It is well known that the best bread-makers find great difficulty in the production of uniformly good bread. This is true of household cooks and of bakers employed in the shops. The bread is sometimes good, more frequently indifferent, and oftentimes positively bad. Sometimes the objectionable qualities of the bread are apparent to the touch, sometimes to the senses of smell and taste, and more frequently in their effects upon health through inferior assimilation.

The sources of this difficulty are various. Some of them may be mentioned. The flour which is employed is variable in excellence as well as in composition. Some of it is made from winter wheat, some from spring wheat; sometimes the

me in my researches upon bread, is about to give to the public the results of his fresh microscopic examination of the structure of the kernel of wheat.

The parts which Mr. Hand has so successfully individualized under the microscope, may be separated to some extent by chemical processes. If the berry, deprived of the two outer coats of true bran by friction with a moistened cloth, be treated with alum solution, then opened along the side opposite the groove, digested with warm water, and carefully pressed, the starch may be quite successfully separated. The residue, consisting of gluten and the immediate investing coats, constitutes some twelve per cent of the whole berry. If the gluten coat be treated with acetic acid, it may, with care, be separated from the layers without.

The extreme outer coats separated by friction with the moistened cloth, contain phosphate of iron and phosphate of magnesia, besides silica and potassa. The ash which has been analyzed by my assistant, Mr. Brooks, is 6.64 per cent, of which 7.70 per cent is phosphoric acid.

The coats next to the gluten contain also phosphates and alkalies. But the great magazine of phosphates, as well as of nitrogenous compounds, is in the gluten layer.

The ash of wheat as a whole contains,—

<table>
<thead>
<tr>
<th>Substance</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Potassa</td>
<td>29.97</td>
</tr>
<tr>
<td>Soda</td>
<td>3.90</td>
</tr>
<tr>
<td>Magnesia</td>
<td>12.20</td>
</tr>
<tr>
<td>Lime</td>
<td>3.44</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>46.02</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>.33</td>
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<tr>
<td>Silica</td>
<td>3.35</td>
</tr>
<tr>
<td>Oxide of iron</td>
<td>.79</td>
</tr>
<tr>
<td>Chloride of sodium</td>
<td>trace</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
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flour is made from "grown" wheat; oftentimes it is heated in
grinding, frequently it is damp and granular, and occasionally
it is sour.

The ingredients of the leaven or yeast with which the ferment-
ed "batch" bread is prepared are not only variable, but the
changes which take place in the yeast itself are influenced by the
quality and condition of the ingredients, by the volume of water
employed, by the temperature to which the mixture is sub-
jected from without, by the heat which is developed in the
process of fermentation within, by the species of ferment which
are added, by the degree of cleanliness maintained, and by the
time during which the various changes are protracted.

*Effects of Fermentation.*

Among the effects which ferment produces in flour,—some
of which are beneficial, and others of which are more or less
hurtful,—there are the conversion of starch into dextrine (a
body nearly allied to gum arabic), and this dextrine into sugar,
and the changing of a portion of the sugar into alcohol and car-
bonic acid, the production of lactic, acetic, butyric, succinic, and
formic acids, the greater or less liquefaction of the gluten, the
formation of ammonia, the production of a dark coloring matter,
the development of microscopic vegetable organisms of various
kinds, and, through the breaking down of the gluten, the greater
or less deterioration of the nutritive properties of the flour.
In the use of recently prepared leaven there is sometimes pro-
duced an ethereal oil which adds to the pleasant taste of the
bread. In the use of old leaven the production of offensive
ethereal oil is uniform.

Of all these effects, it is now generally conceded that the most
important, if not the only essential office of ferment in the making
of bread, is to give to it the requisite porosity, or to make it
"light." This porosity is necessary, as already intimated, that
the fluids taking part in digestion may have surface to act upon.
It is accomplished by the evolution of carbonic acid from sugar,
the alcohol from which exhales with the surplus moisture in the
process of baking.

The production of all other acids than carbonic acid can scarcely
be other than hurtful. The liquefaction of the gluten, due to
their presence in excess, tends to deprive the bread of porosity.
This extreme change causes the dough once distended to collapse
and fall, leaving the bread heavy, or displaying here and there
great cavities.

Liebig proposed the use of lime-water in mixing the dough,—
a suggestion that met with great acceptance. Its office was ob-
vious. It neutralized the acid which was liquefying the gluten.
The lime also combined with the liquefied gluten (albumen) giv-
ing it firmness. The use of alum and sulphate of copper for the
same end may be said to be, in some districts, quite universal.
Dr. Hassall examined twenty-four samples of London bread, and
found alum in all. Dr. Muspratt remarks that what is true of
London may be said of Liverpool and all the larger towns of Eng-
land. Dumas found that sulphate of copper (blue vitriol) had
been in use in Belgium from an indefinitely early period. The
quantity employed, however, was very small. Kuhlmann found
that one baker employed only a pipe-bowl full of the solution for
250 lbs. of bread. It was observed to have the effect to make
inferior flour produce a bread that sold as well as bread from a
better quality of flour, and, besides, the bread retained more water
and was whiter. Alum produced the same results. The action
of the alum, by virtue of its qualities as a mordant, is readily un-
derstood. It combines with albumen and renders it less soluble,
so far arresting the action of the ferment, and thus in a twofold
way lessening the liquefaction of the gluten. The action of sul-
phate of copper is much the same as that of alum, in so far as
combining with the albumen, to form a compound less influenced
by the ferment, is concerned, and it may have a separate specific
effect. It is said to increase the activity of the ferment, but this
may be apparent only, as the effect may be simply to stiffen the
gluten, and thus increase its capacity to hold all the bubbles which
the ferment produces. It is conceivable that it acts somewhat,
though inferior in degree, as corrosive sublimate does to destroy
some of the species of the yeast-plants.

The excessive production of dextrine, with extreme porosity,
makes the bread dry too rapidly, and gives rise to the brittleness
and hardness which characterize the slice of most bakers’ loaves
when left a short time exposed to the air.
Mould poisonous.

The mould, or the organic germs from which it arises, can only be hurtful. To this, it is well known, some of the most painful forms of dyspepsia are ascribed. The significance of this statement may not at first glance be fully appreciated. The existence of microscopic organisms in the various forms of yeast has been established. Whether they be regarded as having an essential office to fulfil in the process of fermentation, as many maintain, or whether the more philosophical view of Liebig be accepted, that they are the incidental concomitants of decay,—the yeast germs everywhere present in the atmosphere finding a fit soil in decaying vegetable organisms,—whether the one view or the other be adopted, it is admitted that the phenomena of fermentation are accompanied by the growth of microscopic vegetable organisms.\(^1\) It is well known that each kind of ferment is capable of reproducing itself, and communicates to the new substance the tendency to break up into bodies of the same character as those into which it is itself resolved. This is true of lactic, acetic, and putrefactive fermentation, as well as of those attending the successive changes of starch into dextrine, sugar, and alcohol and carbonic acid. When now we take into account these doctrines, it is not difficult to conceive that the ferments and their yeast-plants, having escaped destruction by the heat of baking, may produce ill effects when they reach the general circulation.

As a class, microscopic fungi are poisonous. Some of the forms of mould in carelessly dried chestnuts are well known to be poisonous. The form of mould that appears on cheese has long been recognized as a malignant poison. The fungus\(^2\) that appears on rye, and its ill effects, are well known. The wheat-bread distributed among the troops in Paris in 1841 was found to contain in all its crevices a minute red lichen. The rust of wheat and smut of corn are varieties of these poisonous fungi.

\(^1\) Blondean has indicated the particular fungi that attend the different kinds of fermentation. With the alcoholic is the *Torvula cerevisiae*; with the lactic acid, the *Penicillium glaucum*; and with the acetic, *Torvula aceti*.

\(^2\) Ergot.
Dr. Mitchel of Philadelphia long since called attention to the influence of these microscopic organisms on health, and the subject in this immediate connection has been discussed at considerable length; among others, by an English author on hygiene, Dr. Lobb, in a series of articles in the Medical Circular of London, in which he advocates the aerated bread of Dr. Dauglish, made without ferment, to the exclusion of all fermented batch-bread; and in an able paper by Dr. Hunt in the North American Journal of Homoeopathy.

These effects of ferment and the incidental deterioration of the flour by the incipient disintegration of the gluten are undesired concomitants, which, to a greater or less extent, we must accept if we produce the cellular structure by means of ferment.

Why Flour is mixed with Water and Yeast, and kneaded and baked, &c.

The great fact, as already remarked, in the art of bread-making, is the production of surface for the action of the digesting fluids. It is the accomplishment of a permanent cellular structure. Let us trace the series of processes.

The flour is thoroughly mixed with water for what? That the gluten, which, when moistened with water, possesses elasticity and tenacity, may be intimately mixed with the starch, so that when bubbles of gas appear in the midst of the loaf they may everywhere have an elastic and tenacious coat.

The yeast is kneaded thoroughly with the flour for what? That, when the gas-bubbles are produced, their walls may be thin enough to dry, by exhalation of the water, to the consistency required for self-support before the outside burns in the process of baking.

The dough is placed in the oven to be baked for what? That the surface, by extreme drying, may become hard at the moment when the dough has attained its greatest porosity, and hold up the spongy interior while the surplus water is exhaled. The browning of the crust gives rise, by destructive distillation, to some essential oils, kindred with those produced in the roasting of corn or coffee, and agreeable to the senses of smell and taste.