

THE DANGERS OF CERTAIN MINERAL BAKING-POWDERS BASED ON ALUM, WHEN USED FOR HUMAN NUTRITION.

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RECENT studies on vitamins have led us to consider as dangerous the suppression of uncooked foods in our nourishment. Such a suppression is actually never complete. If we consider the alimentary habits imposed on man by modern conditions of life, they may be dangerous for other reasons than simply lack of vitamins.

The economical necessities which urge us more and more to spare time and labour have brought us to industrialise the preparation of our foods, and to increase the use of products requiring little or no preparation before cooking: all sorts of conserves, dressings, condensed foods, extracts, the manufacture and canning of which we know nothing of. Such products, we take it for granted, are examined by the Adulteration Department before being sold to the public, and that satisfies us. Can this attitude of the public be reasonably upheld by physiologists, hygienists, and physicians? Certainly not.

The laws suppressing fraud assure us against finding in our prepared foods, bought daily, bacteria capable of causing serious alimentary intoxications, poisons leading to serious accidents, and antiseptics in big doses. Still, this is not sufficient. It is a well-known fact to pathologists that the daily ingestion of slight doses of feebly nocuous substances can lead to serious functional troubles or organic disorders, if it is repeated for a long stretch of time. There is no doubt that the daily consumption of the above-mentioned foods exposes us to the risks of such slow intoxication. Many of the present laws concerning fraud were passed at a time when physiology and the hygiene of alimentation were far from their present state of development. It was almost exclusively toxicologists and chemists who were entrusted with their establishment. Should not biologists also participate in the present-day revision of these laws?

In the following lines we would like to show by a precise example to what social dangers we are exposed through the daily use of products which have no justification from the physiological point of view, but only mean a slight economy of time to cooks and house-keepers. We speak of the artificial leavens or baking-powders which tend more and more to replace yeast in use by bakers for the manufacture of rusks, biscuits and all other pastries.

The great chemist Liebig was the first who thought of using mineral leavens or baking-powders, instead of yeast, and thus suppressing preliminary fermentation. The baking-powders have proved to be successful in Germany, Austria, Switzerland, U.S.A., where a great deal of pastry is made at home. German "Backpulver" and American baking-powders are well known for their efficiency; they reduce the manipulation of the dough and permit immediate cooking, without the preliminary necessity of letting the mixture rest for a certain time at a temperature of 25°.

What is the composition of the powders or mineral leavens? Carbonic acid is present as bicarbonate of soda; it makes the dough rise, and renders it more digestible; the gas is liberated by an acid salt—biphosphate, bitartrate, or a mixture of bitartrate and tartaric acid. In a well-balanced leaven the proportion of the different salts is always so calculated that after the combined action of water and heat on the mixture of flour and baking-powder, the reaction which takes place, once the carbonic acid is liberated, should leave neither an excess of free mineral acidity, nor alkalinity, which might prove noxious to the organism.

Such mixtures when they were well manufactured were used for a long time without raising any criticism. No country has yet legally prohibited the use of tartaric acid and bitartrate, for this purpose.

But as potassium bitartrate and phosphates are expensive, industry has, for a long time already, been trying to replace them by cheaper products in which the acidity is given by acid salts which are as dangerous as bisulphates or alums of soda, potash or ammonia. Does the repeated absorption of such ingredients raise serious problems of alimentary hygiene?

The use of mineral leavens chiefly constituted by alum and bicarbonate of soda is lawful in the United States, where these baking-powders constitute nearly two-thirds of the total consumption (this consumption amounting actually to several thousand tons a year). In Europe the use of mineral leavens containing alum is virtually forbidden in France, England, Germany, Sweden, Switzerland, Belgium, etc. The introduction of alum into any kind of alimentary product is considered as fraud.

Although Germany could not during the Great War be provided with potassium bitartrate on account of the blockade, her hygienists severely opposed themselves to the production or sale of mineral leavens containing alum, even as an "Ersatz."

We thus see that, on the one hand, nearly all European countries consider the presence of alum or aluminium salts in foods as dangerous and intolerable; while, on the other hand, the United States authorises the production and sale of mineral leavens containing alum in nearly all the states—and yet it is known that in the U.S.A. public hygiene is as strictly controlled as anywhere else. How can one conciliate such divergent opinions on a question of so great an importance in alimentary hygiene?

We may presume that in authorising the consumption of these mineral

products the legislators of the U.S.A. have been governed by the following theoretical ideas: Supposing the leaven to be a well-prepared alum-phosphate baking-powder, that is to say a scientifically calculated mixture of acid calcium phosphate, alum, and bicarbonate of soda, all that remains in the bread when the reaction is finished will be sodium sulphate, acid sodium phosphate, calcium carbonate and aluminium phosphate.

Aluminium phosphate being insoluble will traverse the digestive tract as an inert body. If we take this for granted the question of any possible toxic action of aluminium salts is never raised, since no soluble aluminium salt will, at any moment, exercise its astringent action on the mucous membrane of the digestive tract.

Is the above-mentioned opinion of American hygienists justified? Through a series of experiments which were published in the *Chemical News* in 1888, Maliet brought to light certain defects of manufacture in the baking-powders that were being sold at that time. He furthermore showed that a solution of pepsin of the same hydrochloric acidity as the gastric juice gave aluminium chloride when in contact with alumina, and displaced the phosphoric acid of aluminium phosphate. Aluminium chloride in an acid solution acts like an energetic precipitant of protein matters and the pepsin is carried down with the precipitate, as is always the case when proteins are precipitated in a solution containing ferments.

To these facts, which have been repeatedly confirmed, especially by V. C. Myers, we can add our personal observations¹. Briefly, these are as follows: The aluminium phosphate formed during the action of the leaven is deprived of its water by the baking of the bread, after which it still contains about 17 per cent. of water. In this state of hydration it is easily dissolved in solutions of hydrochloric acid of the same strength as the gastric juice, thus giving soluble aluminium chloride. We have discovered the formation of this astringent salt in the gastric juice of dogs as well as of men, through tests made *in vitro*, as well as *in vivo*. The solubility of aluminium phosphate rises with the proportion of acid contained in the gastric juice, that is to say with the hyperhydrochloric conditions of the subject.

We have, on the other hand, been able to show that, under the alkaline influence of the pancreatic juice, the reprecipitation of the aluminium chloride to the state of aluminium hydrate, at the level of Vater's ampulla, is incomplete owing to the preventive action of bile.

The absorbing of alum-phosphate baking-powder therefore results in the contact of dilute solutions of *aluminium chloride*, with the *gastric, pyloric and duodenal mucosa*. We consider that this fact alone is sufficient to justify the prohibition of alum leavens.

But the presence in the digestive tract of soluble aluminium salts, apart

¹ See G. Schaeffer, G. Fontès, E. Le Breton, Ch. Oberling, L. Thivolle (1928), "Physiological research on mineral leavens. Leavens containing alum." *Bull. Soc. sci. d'hygiène aliment.* **16**, Nos. 1 et 2.

from their possible direct action, raises the question of their absorption, because these salts are considered poisonous for living beings.

Orfila (1814) and Mitscherlich (1840) have seen the effect of intoxication by high doses. This question does not interest us here. Siem (1886) brought to light the results of slow intoxication, but the works that are most important for this discussion are those of Dölcken (1897). This author injected lactate or double tartrate of aluminium and sodium into rabbits and cats, by daily doses of 5 mg. per kg., and thus studied the aluminium intoxication in its chronic manifestations. Anatomico-pathological examinations on cats showed important lesions of the medulla, posterior parts of the column, median parts of the anterior areas, and the tract of Goll. The motor roots of the trigeminal, facial and hypoglossal nerves showed a degeneration of more than half the fibres; there were also many degenerated fibres in the IX, X and XI nerves.

But all these lesions were produced with soluble salts by subcutaneous injections; they are therefore not sufficient to condemn the use of mineral leavens. Before prohibiting the use of these leavens in the name of alimentary hygiene one must examine the following questions:

(1) Whether the aluminium chloride formed in the stomach acts on the digestive ferments?

(2) Whether the frequent contact of this precipitant and astringent salt with the mucous membrane of the digestive tract causes organic lesions?

(3) Whether the daily absorption of aluminium chloride in small quantities provokes certain physiological disorders?

(1) Our personal researches, published elsewhere, have led us to ascertain a marked delay in the gastric evacuation of dogs treated with bread leavened with alum-phosphate baking-powder, as compared with dogs treated with the same bread leavened with baker's yeast. It has furthermore been found that frequent diarrhoea was provoked at the beginning of the treatment, when dogs were given bread containing three times the normal dose of baking-powder¹. The diarrhoea became rarer as the organism grew more accustomed to the treatment, which lasted two months; however it was sufficient to upset the nutrition equilibrium, as shown by important variations of the animals' weight.

If, instead of alum leaven, a corresponding quantity of aluminium phosphate is used in the bread, the purgative effect is much more violent. By using a quantity of aluminium phosphate equivalent to that contained in one dose and a half of leaven, the bread given to the animals provokes such diarrhoea and sickness that this diet cannot be continued for over a fortnight.

The simplest explanation one can give to such a fact is that bread, for which leaven has been used, contains not only aluminium phosphate, but large quantities of calcium salts, which have a moderating action on the intestinal activity.

¹ The ordinary dose of leaven is of 16 g. for 230 g. of flour. The leaven containing 21 per cent. of burnt alum corresponds after reaction to 1.693 g. of alum phosphate, or to 0.374 g. of alum.

(2) After prolonged ingestion of complete and balanced diets, where the energy requirements were supplied by special breads containing alum-phosphate baking-powder, we have observed important lesions of the digestive tract, as well in dogs as in mice. We will not insist on the detail of these researches, but merely state their main results.

Mice were fed for four months on bread containing flour, casein, sugar, fat, milk and salts, proportioned to form a complete food; the vitamins were added as butter, brewer's yeast and green vegetables.

The check Group No. I, composed of 20 couples, was fed on this bread made with yeast; Group No. II received the same, with addition of aluminium phosphate¹; Group No. III got bread of the same composition, but raised with alum baking-powder².

All the specimens of the Groups II and III when submitted to anatomopathological examinations showed serious lesions of the digestive tract, being more or less extensive according to the individuals. We will describe a few of the lesions that were observed.

The most common of them is a paracellular necrosis of the superficial epithelium of the stomach and of the tops of certain intestinal villi. The necrosis can be brutal and attack not only the epithelial layer, but also the vascular tissue of the papillary axis. These lesions resemble greatly erosions met with in human pathology. With certain animals (mice no. 4 in Group No. II, for example) one of the lesions is found to be situated on the pylorus, the other a few millimetres away in the duodenum; a loss of superficial substance characterises these lesions; the epithelium is replaced by a necrotic fibrous magma containing a few polynuclear leucocytes. This necrosis can be important; situated in the fundus of the stomach, they often penetrate in depth, leucocytes having penetrated around the necrotic centres. One never sees these lesions with the mice of Group I, fed on the same bread but leavened with yeast. They are specific and due to the formation of soluble aluminium salts in the digestive duct. To make them disappear it is sufficient to introduce into the food an excess of physiological saline mixture, such as that of Osborne and Mendel.

The hydrochloric acid then reacts with other metallic cations than aluminium; the formation of aluminium chloride is thus prevented, and consequently there is no production of lesions. It is to be noticed that in reality when man absorbs bread or biscuit containing alum baking-powders such a mineralisation of the diet is never realised, and consequently cannot exert its protecting action.

Contrary to the mice, four dogs fed for three or four months on bread containing alum-phosphate baking-powder were not found to have any lesions of the stomach or the small intestine. But there were distinct lesions in the large intestine and especially in the descending colon and the sigmoid flexure.

¹ 2.07 g. of aluminium (Al) for 1000 g. of bread.

² 4.1 g. of aluminium (Al) for 1000 g. of bread.

The congested, oedematized mucous membrane, covered with mucus, is visible even to the naked eye. Histological slides show intense congestion, together with small, subcutaneous haemorrhage, superficially localised; in some places submucous oedema is noticeable.

(3) Are the soluble aluminium salts formed in the digestive duct absorbed? This can be shown by appropriate methods of chemical estimating which put into evidence the aluminium in the organs of animals subjected to diets based on alum-leavened bread (Gies, Steel).

We have made several determinations of this kind, all of which have given positive results.

But the best proof, we think, that aluminium chloride is absorbed by the digestive duct are the troubles occurring in certain physiological functions with animals that have absorbed leavens containing alum, troubles which never occur with animals fed on the same diet, but without aluminium salts.

A. Let us first mention interference with growth in young animals.

On feeding non-adult chickens and rats with perfectly balanced diets rich in vitamins, but based on bread leavened with alum-phosphate baking-powder, a marked delay of growth is noticed as compared with control animals fed on yeast-leavened bread. This delay in the growth is more marked still if the experiments are made on younger animals.

B. The troubles that occur in the reproductive functions are the most characteristic of all those we have observed. Our experiments have been carried out on mice.

In the first series of researches we have observed the reproduction with the three groups of mice already mentioned. During the four months of treatment the twenty pairs of Group I (bread with yeast) had 300 offspring; the 20 couples of Group II (bread with aluminium phosphate) had 193; and the 20 couples of Group III (bread leavened with alum) had only 71.

In a second series of experiments where four groups of ten couples were used the diet was as follows:

Group I. Bread with yeast to which was added 4 % of the Osborne and Mendel salts mixture ("pain à la caséine" constituting the basis of the diet and completed by vitamins).

Group II. Bread with yeast, containing 13 per cent. of the same saline mixture; otherwise the same diet.

Group III. Bread with alum-phosphate baking-powder, 3 doses, that is to say 4.4 per cent. of aluminium (Al), to which was added moreover 4 per cent. of the Osborne and Mendel saline mixture; otherwise the same diet.

Group IV. The same bread as in Group III, but with one dose of alum-phosphate baking-powder, that is to say 1.3 per cent. of aluminium.

After four months of the treatment the following results were observed:

Group I. 46 litters, giving in all 328 individuals. Death-rate during the first week after the birth, 6 per cent.

Group II. 45 litters, 310 individuals; death-rate during the first week, 10 per cent.

Group III. 35 litters, 192 individuals; death-rate during the first week, 23 per cent.

Group IV. 42 litters, 244 individuals; mortality during the first week, 10 per cent.

These results are so outstanding that they need no comment. They can be explained by an elective, specific action of the aluminium ion on the ovary. This action is diminished, though still very marked, when the formation of aluminium chloride in the stomach is reduced by introducing other salts in the diet. As is shown by Group II in the second series of experiments, one cannot put forth as a cause an action due to an over-mineralisation of the diet.

Anatomo-pathological examination confirms these experimental results in a striking manner. While in the case of male mice having absorbed aluminium the testicles remain normal and the spermatogenesis active, the female mice show characteristic lesions of the ovaries.

Ovaries of the Females belonging to the First Series of Experiments.

In its normal state the ovary of a mouse contains a great number of atretic follicles, but their proportion is much greater with the mice of Groups II and III, fed on bread containing aluminium salts. The oocytes of the cortical layer are very rare. When the rare follicles which seem normal at first sight are carefully examined regressive phenomena are observed. *The lesions are non-existent in all the control mice fed on bread with yeast; whereas they are found in every single female mouse which has absorbed aluminium salts; they are particularly distinct with the mice of Group III, fed on bread made with alum-phosphate baking-powder.*

Ovaries of the Females in the Second Set of Experiments.

One is struck with the distinctly reduced dimensions of the ovaries of all the females fed on the alum breads (I and III); the diameter is hardly half that of the ovaries of the control mice. On the microscopic slides the practically total absence of normal follicles is visible at a glance; a few rare ones are formed in the peripheral region, as well as numerous atretic follicles¹. From time to time scars of corpora lutea are to be seen on the slides, or else involuting corpora lutea. *This description holds good for the ovaries of all the mice having undergone a diet based on alum-phosphate baking-powders. These symptoms are never met with in the case of the control mice, fed on bread leavened with yeast, containing doses, however important, of synthetic salt mixture. We therefore consider these lesions as specifically due to the action of aluminium salts.*

The photographic reproduction of several microscopical slides is given in the original work, *loc. cit.*

SUMMARY.

We hope that this summary of our researches will be sufficient to make clear the nature of the danger spoken of at the beginning of this article. We see that certain bodies, not poisons in themselves in the usual sense of the word, can provoke physiological disorders and organic lesions, the etiology of which remains generally unnoticed, when they are absorbed daily for months and years. Such products are most certainly responsible for many illnesses, the frequency of which augments with the alimentary conditions imposed upon us by modern civilisation in a manner inexplicable beforehand.

Our object will have been attained if we succeed in attracting the attention of physicians and hygienists to certain problems, the study of which is perhaps not very attractive but the solution of which is of considerable practical interest.

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