LXXXVII. THE BLACKENING OF POTATOES AFTER COOKING.

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It is well known that potatoes after cooking sometimes darken considerably on the surface. This blackening is distinct from the darkening which occurs with raw potato on exposure to air. In the latter case, there is no doubt that the darkening is due to enzymic oxidation, the oxidisable substance being a phenolic substance of the nature of catechol or other *o*-dihydroxybenzene derivative [Onslow, 1919, 1920] or tyrosine [Bertrand, 1896; Gallagher, 1923].

The darkening of potatoes after cooking appears to be a matter of some considerable importance to those concerned in the growing and sale of potatoes. At the request of the Ministry of Agriculture some experiments were carried out in the Household Arts Department of this College with reference to methods of cooking potatoes in order to find out whether such darkening could be avoided. Some of the potatoes supplied by the Ministry of Agriculture were obtained by the author in order that the problem might be investigated from a chemical standpoint.

In the first experiments "King Edward" and "Great Scot" potatoes were employed and later "Majestic" potatoes were used. Several batches of potatoes of these three varieties have been used in the later experiments, but in the experiments to be described in this paper the potatoes which do not blacken on cooking will be referred to as potatoes A, and those which blacken as potatoes B.

One of the first objects of the present investigation was to devise, if possible, a simple test by means of which it would be possible to tell by examination of a raw potato whether or not a similar potato would blacken on cooking. It is believed that such a test has been discovered. It is described below under the action of nitrous acid on potatoes.

In preliminary experiments, tests were made with various reagents to ascertain if any great difference could be detected between those potatoes which blacken after cooking and those which do not.

Enzymic oxidation.

Transverse sections about 5 mm. thick of potatoes A and B were peeled thinly and exposed to air for one day (in some cases two days) in a bell-jar

containing some chloroform and some water. In both cases very dark brown colours were produced on the surfaces exposed as shown in Plate III, Figs. 1 and 2. Thus enzymic oxidation shows no difference between the two varieties.

The action of nitrous acid.

It was found that all potatoes examined contain a substance (or substances) in greatly varying amounts, which on treatment with nitrous acid followed by an alkali, gives a fine red colour. The amount of the red substance produced in this test was found to vary exactly with the amount of blackening which takes place on cooking. The test is carried out as follows. A transverse section of potato about 5 mm. thick is peeled thinly and covered with 7 % sodium nitrite solution (about 25 cc.) in a small porcelain basin. About 2 cc. of dilute hydrochloric acid (1 volume of concentrated hydrochloric acid to 2 volumes of water) are added and the mixture left for 5 minutes. The liquid is then poured off and the section of potato covered with 16 % sodium hydroxide solution (about 25 cc.). The red colour develops in about 5 minutes, at first chiefly on the outer and inner edges of the fibro-vascular layer of the potato, then through the whole of this layer, but it often extends towards the centre. It is strongly marked where there are eyes in any potato. After some time the coloured substance is partly extracted by the sodium hydroxide solution.

This reaction has not yet been investigated fully. It may be that the nitrous acid reacts with a primary amino-compound and that coupling of the diazo-compound thus produced takes place with a phenoxide on the addition of the sodium hydroxide. The colour may, however, be due partly or entirely to reactions between the nitrous acid and lignocellulose.

The red colour of the sodium hydroxide solution of the substance produced in the reaction is changed on addition of dilute hydrochloric acid and restored on making alkaline. With concentrated hydrochloric acid, on heating, the red substance is decomposed, as the colour is not restored on again making the solution alkaline.

It appears very probable that the production of this colour in the test described above is in some way connected with the blackening which takes place after cooking. If for example the fibro-vascular layer of a potato B, which gives most colour in the test, is completely removed before cooking very little blackening of the remainder is usually noted after cooking.

Photographs of sections of potato after applying the nitrous acid test are shown in Plate III, Fig. 3, for potato A which does not blacken after cooking, and in Plate III, Fig. 4, for potato B, which blackens.

In Plate III, Figs. 6, 7 and 8, photographs are shown of pieces from the surface of the same end of one potato B. Fig. 6 shows a piece of the potato after cooking by steaming, Fig. 7 raw, untreated potato, and Fig. 8 raw, treated with nitrous acid and sodium hydroxide. A resemblance between the photographs Figs. 6 and 8 will be noted, but of course the portion of potato represented in Fig. 6 is black and in Fig. 8 red.

If the water in which potatoes are boiled is treated with nitrous acid and sodium hydroxide, coloured solutions are obtained—deep colours with water in which potatoes which blacken have been boiled and faint colours if the potatoes do not blacken.

The blackening after cooking.

It is extremely probable that this blackening is due to oxidation, but it cannot be due to enzymic oxidation, as during cooking the temperature of a potato is at about 100° for about 20 minutes. Whether the blackening after cooking is due to the oxidation of a phenol or amine has not yet been ascertained. Experiments in support of these statements as to blackening after cooking being due to oxidation are as follows.

(a) If a portion of potato B, which blackens after cooking, is placed immediately it is cooked in a gas free from oxygen and thus allowed to cool in absence of air it does not blacken.

(b) If a piece of cooked potato is placed in a bell-jar containing chloroform and water no effect such as that described above under enzymic oxidation takes place.

The effect of traces of iron on the colour of cooked potato.

It was noticed in the course of this work involving the cooking of potatoes in various ways that a black stain was occasionally obtained on a cut surface of potato when such a stain was not expected.

In one experiment some potatoes were being cooked by steaming on filter-paper in a steamer made from tinned sheet iron. The perforations in the steamer had apparently been made after the sheet iron had been tinned and the edges of the holes were rusting. It was noticed that black marks were obtained on the potatoes (after cooling in the air for some time) which coincided exactly in position with the holes in the steamer. A section of potato B showing these marks is shown in Plate III, Fig. 5.

The explanation of the black marks is probably as follows. The iron compounds from the sides of the steamer holes evidently pass through the filter-paper (as shown by rust marks on standing) and coming in contact with the potato act either catalytically in promoting oxidation, or else combine with the phenolic substances present to produce coloured substances. Most probably both actions take place. Evidence of combination of iron compounds with the phenols is obtained from the fact that somewhat violet colorations are sometimes obtained in such experiments. Ferric oxide alone does not appear to promote blackening.

It is known that it is a ferrous compound that is involved in the catalytic activity of iron in biological oxidations, and since it is iron in the process of rusting (when a ferrous compound will be present) which causes most blackening it appears that the effect of iron in promoting blackening is in part catalytic.

The effect of iron in the process of rusting on the production of blackening after cooking is well shown by steaming a peeled potato in which are inserted some newly cleaned iron nails and allowing the potato to remain exposed to the air some hours after cooking. In view of the extensive use of iron in cooking vessels the action of this metal in causing blackening after cooking must not be overlooked.

The effects of ammonia in steaming potatoes and of acid in the cooking water.

Owing to the well-known effect of ammonia in promoting atmospheric oxidation of polyhydric phenols it was found, as was expected, that potatoes steamed over water containing a little ammonium carbonate were dark in colour after cooking. The effect of the hydrogen ion concentration of the cooking water on the colour of cooked potato is to be investigated, but it has already been found that if potatoes B are cooked in water containing a little acetic acid they are usually a better colour than if cooked in tap-water.

Similarly a section of potato after soaking in dilute acid gives less colour in the nitrous acid test than a piece of the same potato which has been soaked in water only. This might point to a basic substance being concerned in the blackening process. If the acid solution and water used for soaking are subjected to the nitrous acid test a strong reaction is obtained in the acid solution, but not with the water.

Further work on this problem is in progress.

SUMMARY.

A simple test is described by means of which it is considered possible to tell whether or not potatoes will blacken after cooking.

The cause of this blackening as distinct from darkening due to enzymic oxidation is discussed, and attention is drawn to the fact that iron may have a pronounced influence on the degree of blackening observed.

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