nd because the P/M appeared to be elatively constant for butcher weight ligs, a number of calculations were made o estimate protein and fat on the basis of nown moisture content of the muscles. To ascertain the validity of these estimates, they were statistically compared with values obtained from actual hemical analyses.

Table III presents means and standard eviations for the comparison of chemical nalyses of fat and protein to estimations f these two components. Protein was stimated by a regression equation, nultiplication of the P/M constant by per cent moisture, and difference when ctual moisture was known and when at was either chemically determined or stimated by moisture. Fat was calulated by a regression equation only hen moisture was known. The values epresented in Table III indicate that or the 439 carcasses, all estimated alues for fat and protein are similar to hose determined chemically. However, hese averages should not be construed to ndicate that variations do not exist mong individuals. Such evidence is learly indicated by the accompanying tandard deviations and by the correlaon coefficients in Table IV.

As shown in Table IV, correlations etween extracted fat and fat estimated om moisture content were highly gnificant. Because the coefficients ere of high magnitude, confidence was iven to this indirect method of estimaion. Conversely, the direct and indirect rotein estimations were not as highly orrelated. When the regression equaion was employed, some of the relationhips were significant but were of such low magnitude that only minimum variation could be accounted for. Occasional negative coefficients for the 3-marbling score group cannot be explained except that this group included data from heavier weight carcasses as well as lighter weight pork carcasses. The low correlations are believed to be caused by the very narrow range in chemically determined protein and the probable overlap of values due to the difficulty in arriving at absolute values even with the greatest care in carrying out the determinations.

The estimations of protein by the use of the P/M constant are quite similar to the results of the regression equation and would therefore be of little merit for practical application. The protein estimate by difference was, however, more meaningful, and this technique may be useful to approximate protein content indirectly. Subtraction of fat content (calculated from moisture content), actual moisture content, and a constant (for minor muscle components) from 100 gave estimated protein values which were not as highly correlated with chemically determined protein as when the actual extracted fat value was used. Approximately 36% of the accountable variation was lost.


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**MEAT PRESERVATION**

# Oxidative Changes in Cured and Uncured Frozen Cooked Pork


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A PRIMARY OBJECTIVE of this paper is a comparison of patterns of lipid oxidation in frozen cooked meats versus frozen cured meats. Recent work from this laboratory on the freezing preservation of roast beef slices (*2*) and of precooked mullet (*18*) reveals a similar pattern of lipid oxidation as measured by the thiobarbituric acid (TBA) test. Both the meat and fish had moderately high TBA numbers throughout the period of frozen storage, with no significant changes related to storage time. The results were interpreted as a rapid oxidation of the meat lipids during preparation for freezing and upon subsequent thawing. The oxidation was believed to be catalyzed by the ferric cooked meat pigment. The reaction evidently was arrested in the freezer, but proceeded rapidly upon thawing.

The addition of sodium nitrite and salt to meat before heat treatment would be expected to change this pattern. Nitrite converts the meat pigments to the catalytically inactive ferrous nitric oxide hemochromogen; consequently, the stability of refrigerated cured meats to lipid oxidation is high as compared to the stability of cooked meats under the same conditions (*17*). On the other hand, sodium chloride used in curing brines is known to accelerate lipid

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The pattern of lipid oxidation in cured *vs.* uncured frozen cooked pork differed markedly. Heme-catalyzed oxidation during preparation for freezing and thawing, but not during frozen storage, appeared responsible for changes in uncured meat. Cured samples exhibited salt-catalyzed oxidation during frozen storage. The ratio of peroxides to TBA number was 8 to 10 times as high in cured as in uncured meats. This is attributed to the more rapid decomposition of peroxides by the ferric hemes of cooked meat. Rancid odor showed a highly significant correlation (Spearman *rs* = 0.92) with TBA number in both cured and uncured meat. Pigment losses in cured samples were correlated with both peroxides and TBA number (*rs* = 0.87). No completely satisfactory antioxidant was found for frozen cured meat.

oxidation under conditions of low free moisture, as would occur in frozen foods where the water is converted into ice (*7*). Cured meats are notoriously subject to oxidative changes when stored in the freezer.

The cured meat pigment is easily destroyed by fat peroxides, and pigment losses have been shown to parallel lipid oxidation in refrigerated hams (*14*). Similar discolorations would be expected in frozen cured meats. Therefore, measurements of cured meat pigment concentrations are included in the present study.

Although the heme-catalyzed oxidations in cooked meats can be easily prevented by the addition of polyphosphates and vegetable extracts (10), no satisfactory antioxidants have been reported for the protection of cured meats stored in the freezer. The effectiveness of several antioxidants has been determined in this study.

## Methods

**Preparation of Meat.** Fresh pork ham was used exclusively. The meat was trimmed of excess fat and ground twice in Wards' Electric Food Chopper, Model VGS-5169A. The ground meat was mixed thoroughly by hand to obtain a homogeneous product. After addition of the appropriate additives, the meat was thoroughly mixed and weighed into No. 2 cans which were sealed immediately. The cans of meat were heated with free-flowing steam in an autoclave until an internal temperature of 70° C. was reached. The cans were cooled in a running water bath. They were then opened and the contents ground using attachments for the Kitchen-Aid mixer, Model 3-C One-hundred-gram-portions of the ground cooked meat were weighed and pressed into a uniform shape using a hamburger press. The meat was placed in polyethylene bags which were heat sealed and stored at 0° F. (−18° C.). Before assay, samples were thawed by immersing the packages in hot tap water (49° C.) for 25 minutes.

**Lipid Oxidation.** The 2-thiobarbituric acid (TBA) test (*12*) was used to measure the malonaldehyde (a lipid

**Table I. The Effects of Curing Salts and Antioxidants on Frozen Cooked Pork**

| Storage Time, Weeks | Sample Description | TBA No.[a] | Peroxide No. | Cured Meat Pigment, % Retention[b] | Average Sensory Score | Significant Difference in Scores |
|---|---|---|---|---|---|---|
| 0 | Uncured-plain | 0.7 | ... | ... | ... | |
| | Uncured-antiox. | 0.1 | ... | ... | ... | |
| | Cured-plain | 0.0 | ... | 100 | ... | |
| | Cured-antiox. | 0.0 | ... | 100 | ... | |
| 13 | 1[c] Uncured-plain | 4.1 | ... | ... | 3.1 | |
| | 2 Uncured-antiox. | 0.0 | ... | ... | 5.4 | 2, 4 > 1, 3 |
| | 3 Cured-plain | 2.5 | ... | 27.6 | 2.6 | |
| | 4 Cured-antiox. | 0.1 | ... | 86.5 | 5.8 | |
| 23 | 1 Uncured-plain | 5.5 | 4.0 | ... | 3.3 | |
| | 2 Uncured-antiox. | 0.0 | 3.5 | ... | 5.7 | 2, 4 > 1, 3 |
| | 3 Cured-plain | 4.1 | 45.7 | 6.4 | 2.7 | |
| | 4 Cured-antiox. | 1.4 | 20.0 | 70.5 | 5.4 | |
| 47 | 1 Uncured-plain | 4.2 | 5.9 | ... | 3.0 | |
| | 2 Uncured-antiox. | 0.0 | 3.5 | ... | 5.4 | 2 > 1, 3, 4 |
| | 3 Cured-plain | 5.9 | 91.1 | trace | 1.9 | 3 > 4 |
| | 4 Cured-antiox. | 6.8 | 126.0 | approx. 10 | 3.6 | 1 > 3 |

[a] TBA numbers for initial and 13 week assays obtained by standard TBA method. Modified method used for assay of cured samples in subsequent storage periods.
[b] Based on a hematin concentration of 45 p.p.m. in freshly cured sample. Only 65% of total pigment was converted to the nitroso form.
[c] Numbers preceding sample description are used to indicate statistical significance of sensory scores (right column).

**Table II. Effect of Salt and Nitrite on Frozen Pork**

| Storage Time, Weeks | Sample | TBA No. | Peroxide No. | Pigment Ratio 570 mμ to 650 mμ[a] | Average Sensory Score | Significant Difference in Scores |
|---|---|---|---|---|---|---|
| 8 | 1[b] Plain | 4.8 | 10.3 | ... | 2.6 | 4 > 1, 3 |
| | 2 Cured | 0.8 | 13.4 | 2.35[c] | 5.3 | |
| | 3 NaCl | 12.9 | 26.0 | ... | 1.9 | 1 > 3 |
| | 4 $NaNO_2$ | 0.5 | 13.4 | 2.55[c] | 5.4 | |
| 16 | Plain | 6.5 | 6.4 | ... | 2.8 | |
| | Cured | 1.9 | 13.3 | 2.01 | 4.3 | All highly |
| | NaCl | 13.3 | 23.4 | ... | 1.4 | significant |
| | $NaNO_2$ | 1.1 | 5.8 | 2.30 | 5.3 | |
| 27 | 1 Plain | 5.8 | 9.4 | ... | 3.8 | |
| | 2 Cured | 8.5 | 61.1 | 1.40 | 1.7 | 4 > 2, 3 |
| | 3 NaCl | 17.5 | 43.1 | ... | 1.7 | |
| | 4 $NaNO_2$ | 1.8 | 13.7 | 2.19 | 5.4 | |
| 51 | 1 Plain | 7.6 | 10.5 | ... | 3.7 | 4 > 1, 2, 3 |
| | 2 Cured | 9.8 | 60.0 | 1.45 | 1.8 | |
| | 3 NaCl | 15.2 | 34.3 | ... | 1.3 | 1 > 2, 3 |
| | 4 $NaNO_2$ | 2.4 | 21.6 | 2.01 | 5.0 | |
| 66 | Plain | 7.0 | 12.5 | ... | ... | |
| | Cured | 8.1 | 120.7 | 1.26 | ... | |
| | NaCl | 12.6 | 25.6 | ... | ... | |
| | $NaNO_2$ | 2.5 | 16.6 | 1.99 | ... | |

[a] In fresh cured meats, average ratio is 2.59. Falls to a range of 1.3–1.6 when pigment is oxidized (*3*).
[b] Same as footnote *c* Table I.
[c] Initial ratios: cured, 2.54; $NaNO_2$, 2.77.

**Table III. Effect of KCl and NaCl Concentration on Rancidity in Frozen Pork**

| Storage Time, Weeks | Sample | TBA No. | Peroxide No. | Average Sensory Score | Significant Differences in Scores |
|---|---|---|---|---|---|
| 6 | 1[a] Plain | 3.8 | 6.4 | 4.0 | |
| | 2 NaCl, 1% | 7.6 | 10.2 | 2.7 | 4 > 2, 3 |
| | 3 NaCl, 4% | 9.4 | 5.5 | 2.3 | |
| | 4 KCl | 1.7 | 9.9 | 4.6 | |
| 23 | 1 Plain | 4.7 | 3.2 | 3.6 | |
| | 2 NaCl, 1% | 9.5 | 7.7 | 1.9 | 1, 4 > 2, 3 |
| | 3 NaCl, 4% | 14.9 | 19.5 | 1.1 | |
| | 4 KCl | 2.5 | 2.5 | 4.1 | |
| 38 | 1 Plain | 3.8 | 3.1 | 3.1 | |
| | 2 NaCl, 1% | 7.8 | 12.3 | 1.7 | 1, 4 > 2, 3 |
| | 3 NaCl, 4% | 11.8 | 12.6 | 1.3 | |
| | 4 KCl | 1.6 | 2.2 | 3.6 | |
| 52 | 1 Plain | 3.9 | 3.7 | 4.2 | |
| | 2 NaCl, 1% | 9.9 | 8.5 | 2.2 | 1, 4 > 2, 3 |
| | 3 NaCl, 4% | 13.5 | 12.8 | 2.0 | |
| | 4 KCl | 1.8 | 3.4 | 4.7 | |

[a] Same as footnote *c*, Table I.

**Table IV. Antioxidants in Frozen Cured Pork**

| Storage Time, Days | Sample | TBA No. | Peroxide No. | Pigment Ratio 570 mμ to 650 mμ | Average Sensory Score | Significant Difference in Scores |
|---|---|---|---|---|---|---|
| 0 | Control | 0 | 0.9 | 2.37 | ... | |
| | Tripoly. | 0 | 1.1 | 2.42 | ... | |
| | Onion | 0 | 0.6 | 2.47 | ... | |
| | Pepper | 0 | 2.1 | 2.36 | ... | |
| | BHA | 0 | 1.4 | 2.51 | ... | |
| | Trip. + asc. | 0 | 1.4 | 2.47 | ... | |
| 30 | 1[a] Control | 1.3 | 18.6 | 2.28 | 4.3 | 6 > 1 |
| | 2 Tripoly. | 1.7 | 13.5 | 2.25 | 5.0 | |
| | 3 Onion | 0.4 | 14.6 | 2.34 | 5.0 | |
| | 4 Pepper | 0.4 | 12.3 | 2.19 | 5.3 | |
| | 5 BHA | 0.1 | 12.5 | 2.28 | 5.3 | |
| | 6 Trip. + asc. | 0.2 | 16.0 | 2.25 | 5.9 | |
| 97 | 1 Control | 3.8 | 29.6 | 1.84 | 3.0 | |
| | 2 Tripoly. | 2.4 | 22.5 | 2.05 | 3.7 | |
| | 3 Onion | 6.6 | 49.6 | 1.63 | 3.2 | 5, 6 > 1, 2, 3, 4 |
| | 4 Pepper | 3.8 | 31.7 | 1.92 | 3.6 | |
| | 5 BHA | 0.2 | 18.0 | 2.41 | 5.6 | |
| | 6 Trip. + asc. | 0 | 17.4 | 2.13 | 5.9 | |
| 192 | 1 Control | 7.0 | 62.2 | 1.48 | 2.3 | |
| | 5 BHA | 0.3 | 11.5 | 2.00 | 5.1 | |
| | 6 Trip. + asc. | 0.1 | 10.5 | 1.97 | 5.5 | 5, 6 > 1 |
| 370 | 1 Control | 9.1 | 68.6 | 1.35 | 2.1 | 5 > 6, 1 |
| | 5 BHA | 0.6 | 20.3 | 1.85 | 5.1 | |
| | 6 Trip. + asc. | 13.7 | 81.7 | 1.36 | 1.9 | |

[a] Same as footnote *c*, Table I.

**Table V. Ascorbate and Tripolyphosphate as Antioxidants for Frozen Cured Pork**

| Storage Time, Days | Sample | TBA No. | Peroxide No. | Pigment Ratio 570 mμ to 650 mμ | Average Sensory Score | Significant Difference in Scores |
|---|---|---|---|---|---|---|
| 17 | Control | 0.5 | 11.1 | 2.37 | ... | |
| | Asc. | 0.3 | 8.7 | 2.52 | ... | |
| | Tripoly. | 0.4 | 7.4 | 2.41 | ... | |
| | Trip. + asc. | 0.3 | 6.7 | 2.30 | ... | |
| 85 | Control | 3.4 | 31.3 | 2.00 | ... | |
| | Asc. | 1.0 | 11.0 | 2.44 | ... | |
| | Tripoly. | 1.0 | 10.6 | 2.39 | ... | |
| | Trip. + asc. | 0.1 | 6.5 | 2.42 | ... | |
| 154 | Control | 3.5 | 32.6 | 2.20 | 4.9 | None |
| | Asc. | 1.8 | 18.1 | 2.41 | 5.0 | |
| | Tripoly. | 1.8 | 25.0 | 2.33 | 5.4 | Significant |
| | Trip. + asc. | 0.8 | 11.0 | 2.56 | 5.6 | |
| 208 | 1[a] Control | 6.6 | 59.1 | 1.56 | 2.5 | 3 > 1 |
| | 2 Asc. | 2.6 | 19.9 | 2.19 | 5.6 | 2 > 1, 3 |
| | 3 Tripoly. | 4.7 | 28.9 | 1.92 | 3.9 | |
| | 4 Trip. + asc. | 1.7 | 14.7 | 2.23 | 5.1 | 4 > 3 |

[a] Same as footnote *c*, Table I.

oxidation product) which could be distilled from the meat samples. Since nitrite interferes in this test, a modified procedure (*19*) was used for cured samples. In both procedures, duplicate determinations were made and the average was reported as the TBA number—i.e., milligrams of malonaldehyde per 1000 grams of meat.

Peroxides in carbon tetrachloride extracts of the tissue were determined by a modification of the Wheeler method (*16*). Duplicate determinations were made and the average was reported as peroxide number—i.e., milliequivalent of peroxide per 1000 grams fat.

**Pigment Changes.** The concentration of unoxidized cured meat pigment was determined by the acetone extraction procedure of Hornsey (*7*) as modified by Gantner (*6*). Duplicate determinations were made. In other experiments, oxidation of the cured meat pigment was followed by reflectance measurements (*3*).

**Organoleptic Evaluation.** The intensity of rancid odor was rated by a panel of trained judges as described by Tarladgis *et al.* (*13*). Together seven to ten judges rated the samples at any one storage period. Numerical values ranging from 6 (no rancid odor) to 1 (very strong rancid odor) were assigned the judgments, and the average score was calculated for each sample. The Wilcoxon matched-pairs, signed-ranks test was applied to evaluate the significance of differences. Differences are indicated as significant at a level of 0.05 or less.

**Other Tests.** Qualitative tests for nitrite and sulfhydryl groups, both known to be important in the retention of cured meat color, were carried out as outlined by Erdman and Watts (*5*).

## Experimental Results

Experiment 1 compares lipid oxidation and pigment loss in cured *vs.* uncured frozen pork. The effect of the antioxidant combination of sodium tripolyphosphate and sodium ascorbate on both cured and uncured samples was also studied. Ground mixed pork was divided into four batches which were treated as follows: no antioxidants or curing salts; antioxidants but no curing salts; curing salts but no antioxidants; and both curing salts and antioxidants. The proportions of antioxidants were 0.5% sodium tripolyphosphate and 0.22% sodium ascorbate. The curing salts were 2% sodium chloride and 0.03% sodium nitrite. The results of analyses performed at intervals during a year of frozen storage are shown in Table I.

Experiment 2 assesses the over-all effects of salt and nitrite, separately and together, in frozen pork. Two per cent NaCl and 0.03% $NaNO_2$ were added to portions of the same lot of mixed ground pork to obtain samples containing no

additive salt alone nitrite alone and both salt and nitrite. The data are shown in Table II.

Experiment 3 was designed to determine if differences in the initial salt concentration have any effect on the rate of lipid oxidation in uncured frozen meat. The concentrations investigated were 1 and 4% NaCl. KCl, in a concentration of 5.1% (equimolar to 4% NaCl), was also tried. Chang and Watts (*1*) found that NaCl had a much greater catalytic effect than KCl on lipid oxidation in an artificial aqueous fat system. The data are presented in Table III.

Experiment 4 tests the effectiveness of various antioxidants in preventing lipid oxidation and pigment loss in frozen cured meat. Salt (4%) and $NaNO_2$ (0.03%) were added to the ground pork. Separate batches of the meat containing the curing salts were further treated as follows: control (no additional additive); tripoly (0.1% tripolyphosphate); onion (hot water soluble material from 1 gram of green onion tops in 100 grams of meat); pepper (hot water soluble material from 1 gram of green pepper in 100 grams of meat); BHA (0.01% butylated hydroxyanisole, added in the form of Sustane E, Universal Oil Products Co.); and tripoly + asc. (0.1% tripolyphosphate + 0.1% sodium ascorbate). The results are shown in Table IV.

In experiment 5, summarized in Table V, ascorbate and tripolyphosphate were added to cured pork separately as well as in combination. The concentrations used were 0.1% ascorbate and 0.5% tripolyphosphate.

## Discussion

**Pattern of Lipid Oxidation in Cured *vs.* Uncured Samples without Antioxidants.** The TBA numbers of untreated cooked pork (Tables I, II, and III) show the same pattern described in previous studies with frozen roast beef slices (*2*) and mullet (*18*). The values are well above the sensory threshold (believed to be approximately 1.0) at the first storage period but show no progressive increase during storage.

The TBA numbers of cured meats, on the other hand, are initially negligible, but increase progressively throughout storage (Tables I, II, IV, and V). Heme catalysis during freezing and thawing is eliminated by conversion to the cured meat pigment brought about by nitrite, but salt accelerates lipid oxidation in the freezer.

When nitrite alone is added (Table II), the cured meat pigment is fully developed and TBA numbers throughout storage are lower than in corresponding cooked or cured meats. The addition of salt without nitrite results in both heme and salt catalysis, with very high TBA numbers. Increasing the salt concentration from 1 to 4% (Table III) resulted in higher TBA numbers, but even the lower concentration brought about marked increases in lipid oxidation as compared to the unsalted control.

Potassium chloride in the same molar concentration as 4% sodium chloride not only did not accelerate lipid oxidation but actually gave some protection as compared to the control sample (Table III). Chang and Watts (*1*) noted that this salt lacked the marked effect on lipid oxidation shown by sodium chloride and calcium chloride. The observation is not of practical importance, since the bitter taste of the potassium salt would preclude its use in foods.

In comparing peroxide numbers with TBA numbers, several factors must be kept in mind. Peroxide numbers are determined on lipids (mainly triglycerides) extracted from the tissue with carbon tetrachloride. The oxidation of phospholipids or protein-bound lipids would not be measured. On the other hand, the TBA test is applied to distillates from the entire meat sample and should, therefore, measure malonaldehyde from all lipids. Also, peroxides are intermediates in the oxidative de composition of unsaturated fatty acid whereas malonaldehyde is an en product. In the presence of stron peroxide decomposers, such as metals c heme compounds, a lowered ratio c peroxide to malonaldehyde might b expected.

Ratios of peroxide to TBA numbe have been calculated for cured an uncured meats, with and without variou additives. The results are summarize in Table VI. The ratios for uncure meats are strikingly low as compared t those for cured meats—i.e., very littl peroxide can be extracted from uncure frozen meats as compared to the amoun obtained from cured samples at the sam TBA level. Similar results were inter preted earlier as evidence that heme catalyzed oxidation in the cooked meat is largely confined to lipid fractions nc extracted by carbon tetrachloride, where as salt catalyzes oxidation in the tr glycerides which are extracted in th peroxide test (*15*).

The additional data now available o uncured salted samples throw doubt o this interpretation. The addition of sa to uncured meat did not increase th ratio of peroxide to TBA numbe significantly. Furthermore, meats cor taining nitrite but no salt showed th same high peroxide to TBA ratio a the cured, salted samples. The inter pretation that peroxides cannot ac cumulate in cooked meats because c their rapid decomposition by the ferri pigments is more consistent with th facts.

**Antioxidants.** In this, as in earlie work from this laboratory, tripolypho phate plus ascorbate eliminated th heme-catalyzed lipid oxidation of ur cured cooked meats (Table I). Tr polyphosphate alone, even at much lowe concentrations, has proved effectiv (*10*). Tripolyphosphate also protec refrigerated cured meats (*14*).

This was not true of frozen cure meats. Tripolyphosphate alone, at cor centrations of 0.1% (Table IV) a

**Table VI. Ratio of Peroxide Number to TBA Number**

| Sample Composition | No. of Samples | Peroxide:TBA Range | Peroxide:TBA Av. |
|---|---|---|---|
| Uncured, no addition | 13 | 0.68–2.8 | 1.4 |
| Uncured, salt added | 12 | 0.59–2.5 | 1.6 |
| Cured, no antioxidant | 25 | 5.0–27 | 11 |
| Cured, unsalted | 7 | 5.3–27 | 10.4 |
| Cured, tripoly. | 10 | 8.0–21 | 13 |
| Cured, BHA or tripoly + ascorbate | 14 | ...[a] | ...[a] |

[a] Calculation meaningless. Ratios very high in early storage periods. TBA numbers generally ranged from 0 to 0.2, and peroxides from 10 to 20.

**Table VII. Rank Correlations**

| Observations Correlated | Sample Composition | No. of Samples | Spearma $r_s$[a] |
|---|---|---|---|
| TBA and peroxide | Cured only | 18 | 0.84 |
| | Uncured only | 20 | 0.91 |
| | Cured and uncured | 40 | 0.60 |
| TBA and rancid odor | Cured only | 43 | 0.82 |
| | Uncured only | 25 | 0.85 |
| | Cured and uncured | 32 | 0.92 |
| Peroxide and rancid odor | Cured only | 43 | 0.80 |
| | Uncured only | 24 | 0.68 |
| | Cured and uncured | 32 | 0.56 |
| TBA and pigment loss | Cured | 18 | 0.87 |
| Peroxide and pigment loss | Cured | 18 | 0.87 |

[a] All values highly significant.

.5% (Table V) was not protective. scorbate alone gave some protection in ıe one experiment in which it was tried Table V), but this compound behaves ratically when added to meat, sometimes accelerating rancidity. Hot water ctracts of green onion tops and green eppers had no protective effect.

The combination of tripolyphosphate ıd ascorbate gave excellent protection uring the first few months of storage, ut the treated samples were highly ıncid at 47 weeks (Table I) and 1 ear (Table IV). The increase in lipid xidation is sudden and drastic and may ɔincide with loss of the ascorbate, alough this has not been demonstrated.

BHA was the most effective of the ntioxidants tried in preventing lipid xidation (Table IV). Unfortunately, though no rancid odor was present in ıe BHA-treated samples even after a ear of storage, an unidentified off-odor as evident at least during the last few ıonths of storage. The peculiar medicinal" odor detracted from the alatability of the cured meat. Further ıvestigation of this problem is needed efore BHA can be recommended as an ıtioxidant under these conditions.

Cured meat protected either with HA or with tripolyphosphate plus scorbate (up to the time of the sudden ıcrease in oxidation) showed extremely igh peroxide to TBA ratios. These ıtioxidants appear to prevent peroxide ecomposition. Privett (*9*) has offered vidence that the synergistic activity of scorbate may be due, at least in part, to s ability to delay peroxide decomposiɔn.

**Sensory Scores and Pigment hanges.** Statistical evaluations of the ɔrrelation between several of the tests sed were obtained using the Spearman ank correlation (*11*). The results are ummarized in Table VII.

The correlation of rancid odor with BA numbers is very high. This is true ɔth for cured and for uncured samples, and the correlation increases further when the total number of cured and uncured samples are ranked together. When it is considered that the organoleptic ratings were made over a period of many months, with no standards for comparison, a correlation coefficient of 0.92 is surprisingly high.

Peroxide number also correlates well with sensory scores in cured samples. The correlation coefficient is lower when uncured samples are ranked and, as might be expected, drops still more when cured and uncured samples are lumped together. Peroxides appear to be a less useful measure of rancidity than the TBA test, especially when sample treatments affect peroxide stability. The difficulty of designating a "threshold" peroxide number for rancid odor is evident when sensory scores are compared with peroxides in cured and uncured meats.

To correlate pigment losses in cured meats with rancidity tests, pigment ratios in Tables II, IV, and V were calculated for ranking purposes as per cent retention, assuming that a ratio of 1.3 represents complete pigment destruction. These results could then be combined with pigment retentions by the Hornsey method (Table I). Pigment loss showed a high degree of correlation with both the TBA and peroxide numbers. Any antioxidant treatment which retarded lipid oxidation also retarded pigment loss.

All samples in Experiment 1 gave positive sulfhydryl tests throughout a year of storage. Freezing has been shown to protect sulfhydryl groups (*4*). Free nitrite was present in the cured sample throughout but rapidly disappeared from the cured sample containing ascorbate. This observation is in agreement with earlier work (*8*).


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**'OTATO SUGARS**

# 'he Quantitative Analysis of Glucose ınd Fructose in Potatoes


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THE COLOR DEVELOPMENT in potato chips depends upon the formation of rown pigments during the frying of .e potato slices in an oil bath. Habib ıd Brown (*7*) and Shallenberger (*12*) ɔnclude that this color development results from the reaction between reducing sugars and amino acids. The exact mechanism of this reaction is not known; it is influenced by a number of factors, such as pH, temperature, concentrations of reactants, and catalysts. A number of investigations (*3, 5, 6, 8, 10, 13*) show that the sugar and amino acid contents vary considerably among potato varieties, and are influenced by environmental, cultural, and storage conditions.

To determine the concentrations of sugars in potatoes which had been subjected to diverse growing and storage conditions, a rapid, sensitive, and ac-

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