**Table VI. Results from Determination of Surface and Pulp Residues in Apples Treated by Dipping in Diphenylamine Solutions**

| Concentration, P.P.M. | Time in Storage, Days | Variety | Residue Found, P.P.M. Surface | Pulp | Surface + pulp | Residue Found, P.P.M., Whole Fruit Analysis |
|---|---|---|---|---|---|---|
| 2000 | 112 | Arkansas | 1.81 | 1.90 | 3.71 | 3.83 |
| | 125 | Rome Beauty | 1.77 | 1.95 | 3.72 | 3.50 |
| 3000 | 125 | Rome Beauty | 2.19 | 1.93 | 4.12 | 4.90 |

A number of samples of apples treated by dipping in diphenylamine solution were analyzed by both methods. The results are presented in Table III, and indicate that both methods are in excellent agreement.

The results obtained by the colorimetric method from the determinations of diphenylamine residues are shown in Tables IV and V. Table IV gives the results obtained from apples that were treated by dipping and Table V from wrapped apples. Two of the control samples contained negligible amounts, and the remainder contained no apparent diphenylamine. No corrections have been made for controls in calculating the results of treated apples.

Three samples of dipped apples were analyzed for surface and pulp residues, as well as total residue. The results, shown in Table VI, indicate that diphenylamine penetrates the skin, as approximately equal amounts were found on the surface and in the pulp.

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*Received for review May 15, 1958. Accepted April 25, 1958. Work supported in part by the Biological Sciences Branch, Marketing Research Division, U. S. Department of Agriculture.*


**ANTIOXIDANT TOXICITY**

# Toxicological Studies on Sesamol


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**Sesamol, a constituent of sesame oil, possesses antioxidant properties, and is at least partly responsible for the stability of this important oil. Sesamol can now be produced commercially and is a potentially useful antioxidant. Extensive toxicological investigations have shown that it is nonirritant to the skin and does not cause skin sensitization. Long-term feeding of twice recrystallized sesamol to rats had no effects on growth, mortality, or blood morphology. Deposits of pigment occurred in the kidneys of the female rats but were unrelated to the dietary levels of sesamol. A total of 20 proliferative lesions occurred in 134 rats fed sesamol. Sixteen of the lesions were benign, two were malignant, and two were questionable. No such lesions were found in the controls, nor in rats receiving the two lowest dosages of sesamol.**


Chemical and physiological properties of sesame oil have been reviewed by Budowski and Markley (*4*). They stated that "sesame ranks ninth among the 13 vegetable oil crops which account for approximately 90% of the world's production of vegetable oils." They also pointed out that sesame oil "contains more unusual minor components and exhibits more unusual chemical and physiological properties than any other common edible oil. Some prominent characteristics of sesame oil are its stability on prolonged storage, its resistance to oxidative rancidity, and its ability to protect other fats against rancidity. These properties have been ascribed to the minor constituents—i.e., sesamin, sesamolin, and sesamol. In 1941, Olcott and Mattill (*13*) suggested that sesamol might be responsible for the stability of sesame oil and for its antioxidant properties.

Budowski, Menezes, and Dollear (*5*) demonstrated that the processing treatments of sesame oil released sesamol from its bound form (sesamolin) and resulted in increased stability of the oil. Because of its marked stability sesame oil is used in pharmaceuticals as a vehicle for fat-soluble substances, and finds extensive use in the food industry. Probably, the antioxidant properties of sesame oil are, in part at least, responsible for its value in certain pesticide formulations (*7, 8, 10, 11*) in which constituents such as rotenone and pyrethrin are subject to oxidative deterioration. The structures of sesamin and sesamolin have been proved recently (*2*). The relationship of sesamin, sesamolin, and sesamol, and the derivation of the latter by hydrolysis of sesamolin are shown in Figure 1. The isolation of the disaminyl ether from the hydrolyzate of sesamolin by Haslam and Haworth (*12*) suggests the formula shown for samin.

Sesamol is the methylene ether of oxyhydroquinone. From a structural point of view, sesamol probably would be a more effective antioxidant than either sesamolin or sesamin—both of which lack a free hydroxyl group. Budowski (*3*) found that sesamol possessed marked antioxidant activity in lard and vegetable oils, and that neither sesamolin nor sesamin had any appreciable antioxidant activity when tested by the active oxygen method. However, Gersdorff, Mitlin, and Beroza (*9*) found that sesamol is not active as a pyrethrin synergist, whereas sesamin and sesamolin are powerful synergists. These contradictory results suggest that a synergistic action toward pyrethrin in the presence of a biological factor may not be a simple antioxidant action. Observations on

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the antioxidant efficiency of a compound occurring naturally in an oil of established nutritional value, the need for an antioxidant to stabilize edible fats and oils, and the fact that sesamol can be produced synthetically provided the impetus for the study of acute and chronic toxic effects of sesamol.

### *Experimental Procedures and Results*

Two samples of sesamol, prepared by the Trubek Laboratories, Inc., East Rutherford, N. J., and supplied by the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, were used in these studies. The sample described as "commercial" had been recrystallized once, while the sample designated as "pure" had been recrystallized twice. In view of the uses proposed for sesamol, toxicological studies were limited to its effects on mucous membrane, on the skin, and to the effects of long-term feeding to rats of diets containing various concentrations of sesamol.

**Tests for Irritant Properties.** Tests for local irritant action were made on the mucous membranes of the rabbit eye, on the skin of rabbits and rats (*1*), and skin sensitization tests were made on guinea pigs and human volunteers. All these tests were made with pure sesamol.

**Mucous Membrane.** Two concentrations of sesamol in aqueous solution were used. One solution contained 25 mg. per ml.—one drop being equivalent to 1.2 mg. of sesamol. The other solution contained 50 mg. per ml.—one and two drops being equivalent to 2.3 and 4.6 mg. of sesamol, respectively. Six rabbits received 1.2 mg. of sesamol in the conjunctival sac, four received 2.3 mg., and six received 4.6 mg. In each rabbit, the contralateral eye received a comparable volume of water and served as a control. The symptomatic response was the same in all rabbits and at all dosage levels. Within 4 hours, edema of the nictitating membrane, slight swelling of the palpebral folds, and conjunctivitis were present. Twenty-four hours later slight chemosis of the treated eyes was still apparent in rabbits given 2.3 or 4.6 mg. of sesamol, and the eyes treated with 1.2 mg. appeared normal. After 48 hours, all rabbits treated with 1.2 or 2.3 mg. of sesamol had normal appearing eyes. At this time three of six rabbits treated with 4.6 mg. of sesamol had slightly injected nictitating membranes, but the eyes were normal otherwise.

**Skin.** Patch test. An amount of a 5% aqueous solution of sesamol equivalent to 50 mg. per kg. was applied to a thin cotton pad 7.5 × 9 cm., and placed over the shaved right flank of each of three rabbits for 4 days. The pad was secured in place by a bandage, a square of rubber sheeting being placed between the pad and bandage to prevent evaporation. No local or systemic reactions were observed.

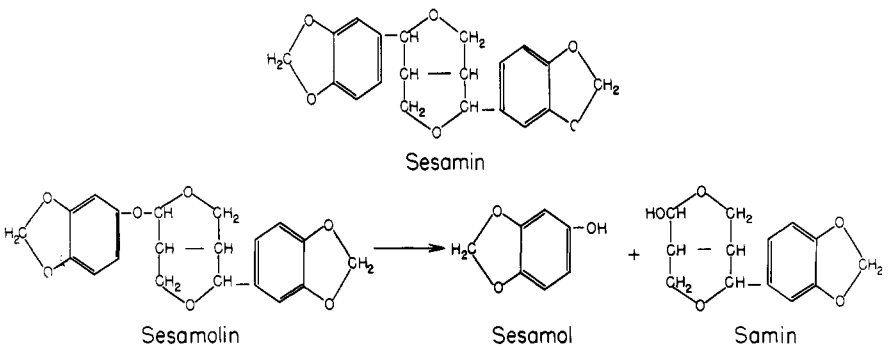


Figure 1. Structural formulas of related sesame oil constituents

Topical application. Sesamol in amounts equivalent to 50 mg. per kg. of body weight were dissolved in cotton seed oil or ethyl alcohol and applied daily for 30 days to the depilated skin of rats in an area 3 cm. in diameter. No local or systemic reactions were produced.

Intradermal tests. Ten rats were injected intradermally with 0.1 ml. of an aqueous solution containing 5 mg. of sesamol. Within 4 days necrosis at the site of injection appeared in six of the rats.

In rabbits, a series of wheals was made on the abdomen with 0.16 to 5 mg. of sesamol dissolved in 0.1 ml. of water. Thirty minutes after the intradermal injection of the sesamol, 0.5 ml. per kg. of body weight of a 1% solution of trypan blue was injected intravenously. Observations on the staining of the wheals were made at 30-minute intervals during the first 2 hours, and at the end of 24 hours. Marked irritation, as judged by staining, was observed within 30 minutes in the wheals produced by 0.5 mg. or more of sesamol. Wheals produced by smaller amounts of sesamol remained unstained. As controls, water and 0.05 ml. of a 4% solution of formaldehyde were used. Staining appeared in the formaldehyde wheal, but not in the water wheal.

**Skin Sensitization.** Twelve albino guinea pigs were used as follows: Four were given intracutaneous injections of 0.1 ml. of a 0.1% solution of sesamol in 0.8% sodium chloride; four were treated topically with 0.1 ml. of a 1% solution of sesamol in ethyl alcohol; and four guinea pigs were treated topically with 0.1 ml. of a 1% solution of sesamol in cottonseed oil. The sesamol in the respective vehicles was administered on alternate days until 10 applications were made. Fifteen days after the last applications, the "challenging" dose of sesamol in the respective carrier-vehicle was administered slightly below the sensitizing area.

None of the sensitizing doses produced irritation. After the challenging dose was administered no reactions were observed, other than a slight hyperemia in two guinea pigs receiving the challenging dose intracutaneously. The hyperemia was still present 24 hours later, but was questionable after 48 hours.

In five human subjects, nine sensitizing doses, 24 hours apart, of 1.25 mg. of sesamol dissolved in alcohol were applied to the anterior cubital surface of the right arm. Twelve days after the last sensitizing dose, the challenging dose was applied. No signs of hyperemia or irritation were produced by either the sensitizing or the challenging doses.

**Chronic Toxicity Studies on Rats.** Long-term feeding experiments on rats were carried out with both commercial and pure sesamol. The basal diet on which the control rats were placed had the following percentage composition: yellow, degerminated cornmeal, 73; casein, 10; linseed oil cake meal, 10; ground alfalfa, 2; bone ash, 1.5; sodium chloride, 0.5; and U.S.P. cod liver oil, 3. The highest dietary level of sesamol fed was 1.0% added to the basal diet. A sufficient amount of the 1.0% sesamol diet was prepared periodically so that aliquots diluted with the basal diet yielded dietary levels of 0.5, 0.25, 0.125, 0.06, 0.03, 0.016, and 0.008% sesamol. Weanling rats from this laboratory's colony were used. Five rats of each sex, maintained separately, were placed on the control and on each experimental diet. The amounts of commercial and pure sesamol available permitted continuation of the feeding experiments for 400 and 634 days, respectively. Free access to food and water was permitted at all times. Food consumption for each group and the body weight of each rat were recorded at weekly intervals during the first 300 days. Thereafter the body weight of each rat was recorded at monthly intervals. At each weighing period, careful comparisons were made of the general appearance and well-being of all rats receiving sesamol with those on the control diet.

Hematological studies consisting of hemoglobin determination and erythrocyte and leucocyte counts were made at approximately 3-month intervals during

the first 400 days on control rats and on those on a dietary level of 1% sesamol. In the case of rats receiving "pure" sesamol (0.008 through 0.5%), hemoglobin determinations were also made just before autopsy after approximately 634 days on the diets. Upon termination of the feeding periods all surviving rats were sacrificed, and examined for gross evidence of abnormalities. In the case of rats receiving commercial sesamol and sacrificed at the end of 400 days, the weights of liver, spleen, heart, kidneys, and testes were determined. The following organs of all rats were fixed in 10% formalin: brain, hypophysis, thyroid, parathyroid, heart, lung, liver, spleen, kidney, adrenal, pancreas, stomach, ileum, bladder, and gonads. Hematoxylin-eosin stained paraffin sections were prepared for histopathological examination.

The average body weights of each group of rats on the various diets at periodic intervals and at the end of the feeding tests are given in Table I. Neither the commercial nor the pure sesamol at any dietary level had any appreciable effect on growth or final body weights of the male rats at the end of 400 days. The same is true of female rats fed pure sesamol, while the three highest dosage levels of commercial sesamol caused a slight decrease in final body weights of female rats. These decreases in body weights are of questionable significance, except on the 1% dietary level where $P = 0.05$. The hemoglobin values and erythrocyte and leucocyte counts were within the normal range for all rats on both samples of sesamol. The mortality was unrelated to the dietary levels of either sample of the compound, as shown by the parenthetical values in Table I.

The mean body weights and mean organ weights expressed as grams per 100 grams of body weight, for control rats and those fed commercial sesamol for 400 days, are given in Table II. These data show a statistically significant increase in liver weight of female rats on the three highest dosage levels of commercial sesamol. Increased significance may be attached to this finding by its correlation with the lower final body weights of these same rats as compared with those of the controls. No such decrease in body weight nor increase in liver weight were found in female rats receiving 0.25 and 0.5% pure sesamol for 634 days as shown in Table II. These results may implicate an impurity in the commercial sample.

**Pathological Findings.** The following findings concern animals receiving commercial sesamol for 400 days.

**Gross Pathology.** All surviving rats on the various dietary levels of commercial sesamol and the appropriate controls were sacrified at the end of 400 days. No gross evidence of tumors was seen in either the control or experimental rats. Consolidation of one lung lobe was present in one control male, and a small abscess was found on the liver of one control male. The organs of all control females appeared normal. A number of the animals receiving sesamol exhibited hemorrhagic or consolidated lungs, but this finding was unrelated to sex or dosage of sesamol. One rat on 0.25% sesamol had an ovarian cyst, and a kidney cyst was found in one female rat on 1% sesamol.

**Microscopic Pathology.** In the epithelium of the renal convoluted tubules of a good many of the female rats on the various dosage levels of commercial sesamol for 400 days there was somewhat more deposited pigment than in the controls. There was much variation in the amount of this pigment from animal to animal and little relationship to the dosage of sesamol fed. One female rat on 1.0% commercial sesamol showed no more renal pigment than the controls. Although this pigment was presumably hematogenous and the spleens of several of the treated females were rather heavily pigmented, the hemoglobin values of all rats on both samples were within the normal range.

The lungs from the experimental animals of both sexes showed about a 10% incidence of well developed inflammatory change, which was absent in the controls. The degree of this change was not recognizably related to the dosage of sesamol fed. A number of the affected lungs showed bronchiectasis, and in some there was irregular peribronchial fibrosis. In one animal, a nodule of peribronchial fibrous tissue contained some distorted islands of epithelial cells—probably derived from bronchial glands and superficially resembled a tumor.

A number of hyperplastic changes were found in the sesamol-fed rats, but no lesions were seen in the nine controls or in the 19 animals receiving the two lowest dosage levels of sesamol.

All the papillary lesions of the urinary tract were small. The epithelium over papillary projections of stroma in some lesions showed little qualitative change, although in two instances it was modified toward the squamous cell type and was distinctly thickened irregularly. There was no pronounced cellular irregularity and the appearance of the lesions did not suggest malignancy.

The stomach tumor was located partly in the submucosa but communicated with the mucosa, which was superficially ulcerated over it. The muscularis mucosae was absent in this region, and the base of the lesion extended almost to the muscularis. Although the border of the lesion was well defined and the cells were fairly uniform, the glands were larger and less uniform than normal, and the cells showed some mitotic activity. Whether this lesion should be regarded as possessing limited maligant properties can be debated, but it is in any event a relatively localized lesion.

The lung adenoma resembled the lesions appearing spontaneously in some strains of mice. It was of the type seen commonly in rats which received acetylaminofluorene, a well established carcinogen (*6*).

The uterine polyp was composed mostly of edematous hyperemic connective tissue and probably was not a true neoplasm. Table III shows the types and frequency of hyperplastic changes in animals receiving commercial sesamol for 400 days.

The following findings concern animals receiving pure sesamol.

To conserve the supply of pure sesamol all male and female rats on the 1.0% dietary level were sacrificed at the end of 400 days. Rats on dietary levels of 0.5% or less of pure sesamol and their appropriate controls were sacrificed at the end of 634 days. Prior to completion of the 634-day feeding period of pure sesamol, one male rat with a mammary tumor on a dietary level of 0.016% was sacrificed at the end of 576 days. One female rat receiving 0.5% pure sesamol was moribund at 408 days and was sacrificed. One female rat on each of the dietary levels of 0.016, 0.03, 0.125, and 0.25% pure sesamol for approximately 575 days was autopsied because of large incapacitating mammary tumors.

The following gross and microscopic findings were obtained.

**Gross Pathology.** Of the rats receiving 1.0% pure sesamol for 400 days, one male had bladder stones, and two showed some consolidation of the lungs. All other organs of the males and all organs of the females appeared normal.

Among the animals fed 0.5% pure sesamol or less and sacrificed at 575 or 634 days, an occasional rat on each dosage level had bladder stones, browning of the uterine horns, and lung consolidation. One kidney of each of two female rats had a cyst. These gross abnormalities, which were absent in the controls, were unrelated to the dosage of sesamol fed.

**Microscopic Pathology.** As in the case of rats sacrificed after 400 days on various dosage levels of commercial sesamol, the kidneys of the female rats receiving pure sesamol showed brown pigment in some of the epithelial cells of the proximal convoluted tubules. This pigment was often in the form of coarse lumps, some of which appeared to have been discharged into the tubule lumen. The kidney of one control female rat contained a small amount of this pigment, about the same amount of pigment noted in approximately half of the treated female rats. The remaining treated female rats showed more, but the quan-

**Table I. Average Body Weights of Rats Receiving Diets Containing Various Concentrations of Sesamol (Pure or Commercial)**

(Five rats of each sex per group at start)

| Compound in Diet | | Average Body Weights, Grams[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days | | | | | | | | | | | | |
| | | 0 | 50 | 100 | 200 | 300 | 400 | 634 | 0 | 50 | 100 | 200 | 300 | 400 | 634 |
| Name | % | Male | | | | | | | Female | | | | | | |
| Pure sesamol | 0.0 | 53 | 236 | 292 | 366 | 390 | 413 | 410 (5) | 49 | 187 | 220 | 259 | 273 | 301 | 309 (1) |
| | 0.008 | 51 | 237 | 274 | 339 | 366 | 388 | 408 (2) | 50 | 179 | 215 | 262 | 298 | 327 | 353 (2) |
| | 0.016 | 52 | 252 | 304 | 369 | 408 | 432 | 428 (4) | 50 | 166 | 199 | 238 | 273 | 318 | 360 (4) |
| | 0.03 | 51 | 224 | 274 | 353 | 389 | 413 | 401 (4) | 48 | 184 | 234 | 260 | 297 | 328 | 346 (3) |
| | 0.06 | 52 | 231 | 286 | 346 | 392 | 396 | 389 (2) | 50 | 173 | 213 | 255 | 281 | 299 | 314 (4) |
| | 0.125 | 52 | 251 | 304 | 380 | 409 | 430 | 404 (4) | 49 | 178 | 213 | 252 | 286 | 312 | 357 (3) |
| | 0.25 | 53 | 257 | 295 | 358 | 402 | 418 | 406 (2) | 50 | 180 | 222 | 259 | 273 | 298 | 313 (3) |
| | 0.5 | 52 | 251 | 302 | 375 | 402 | 428 | 450 (3) | 47 | 172 | 206 | 246 | 262 | 273 | 298 (3) |
| | 1.0 | 53 | 217 | 262 | 318 | 335 | 380 (4) | ... | 51 | 168 | 196 | 221 | 267 | 301 (3) | ... |
| Commercial sesamol | 0.0 | 53 | 228 | 275 | 343 | 375 | 395 (5) | ... | 53 | 194 | 235 | 272 | 301 | 320 (4) | ... |
| | 0.008 | 52 | 248 | 294 | 345 | 376 | 387 (5) | ... | 51 | 179 | 219 | 257 | 289 | 324 (5) | ... |
| | 0.016 | 51 | 223 | 269 | 338 | 376 | 393 (4) | ... | 52 | 179 | 231 | 272 | 293 | 307 (4) | ... |
| | 0.03 | 52 | 257 | 317 | 395 | 418 | 426 (5) | ... | 53 | 190 | 244 | 285 | 317 | 343 (4) | ... |
| | 0.06 | 53 | 249 | 306 | 389 | 405 | 437 (2) | ... | 53 | 179 | 229 | 271 | 305 | 337 (5) | ... |
| | 0.125 | 52 | 229 | 307 | 381 | 409 | 425 (3) | ... | 52 | 195 | 231 | 276 | 299 | 338 (5) | ... |
| | 0.25 | 51 | 235 | 297 | 372 | 403 | 420 (5) | ... | 55 | 198 | 237 | 264 | 285 | 295 (5) | ... |
| | 0.5 | 53 | 234 | 292 | 371 | 408 | 428 (4) | ... | 54 | 184 | 222 | 258 | 277 | 295 (5) | ... |
| | 1.0 | 55 | 227 | 271 | 336 | 377 | 402 (5) | ... | 54 | 180 | 211 | 247 | 272 | 282 (5) | ... |

[a] Number within parenthesis represents number of rats surviving and autopsied on termination of the experiment.

**Table II. Body Weights and Organ Weights of Male and Female Rats Fed Various Concentrations of Sesamol (Commercial and Pure)**

(Five rats of each sex per group at start)

| Sesamol Fed, % | No. of Rats | Body Weights, G. Mean ± SE[a] | Organ Weights, G./100 G. Body Weight | | |
|---|---|---|---|---|---|
| | | | Liver, mean ± SE | Kidneys, mean ± SE | Testes, mean ± SE |
| | | Commercial, Approximately 400 Days | | | |
| Males | | | | | |
| 0.0 | 5 | 395 ± 8.81 | 3.20 ± 0.13 | 0.62 ± 0.02 | 0.88 ± 0.02 |
| 0.25 | 5 | 420 ± 10.97 | 2.90 ± 0.10 | 0.61 ± 0.02 | 0.84 ± 0.02 |
| 0.5 | 4 | 428 ± 8.56 | 2.82 ± 0.08 | 0.56 ± 0.02 | 0.85 ± 0.02 |
| 1.0 | 5 | 402 ± 8.92 | 2.94 ± 0.13 | 0.59 ± 0.02 | 0.88 ± 0.04 |
| Females | | | | | |
| 0.0 | 4 | 320 ± 11.73 | 2.50 ± 0.08 | 0.53 ± 0.03 | |
| 0.25 | 5 | 295 ± 14.77 | 3.12 ± 0.14[b] | 0.56 ± 0.02 | |
| 0.5 | 5 | 295 ± 16.43 | 3.05 ± 0.18[c] | 0.57 ± 0.02 | |
| 1.0 | 5 | 282 ± 9.48 | 3.43 ± 0.14[b] | 0.59 ± 0.02 | |
| | | Pure, Approximately 634 Days | | | |
| Males | | | | | |
| 0.1 | 5 | 410 ± 11.16 | 2.75 ± 0.06 | 0.61 ± 0.01 | 0.83 ± 0.02 |
| 0.125 | 4 | 405 ± 23.40 | 2.60 ± 0.22 | 0.66 ± 0.02 | 0.90 ± 0.04 |
| 0.25 | 2 | 406 | 2.71 | 0.68 | 0.91 |
| 0.5 | 3 | 450 ± 12.84 | 2.61 ± 0.20 | 0.58 ± 0.0 | 0.73 ± 0.09 |
| Females | | | | | |
| 0.0 | 1 | 309 | 3.06 | 0.56 | |
| 0.125 | 2 | 357 | 2.75 | 0.59 | |
| 0.25 | 3 | 313 ± 17.90 | 2.79 ± 0.02 | 0.57 ± 0.009 | |
| 0.5 | 3 | 298 ± 13.91 | 3.12 ± 0.14 | 0.57 ± 0.11 | |

[a] SE = standard error of the mean. [b] $P = <0.01$. [c] $P = <0.05$.

tity of pigment was not distinctly related to the dosage of sesamol, being quite large in one of the animals on the smallest dosage. There was nothing to suggest kidney injury in these animals. The kidneys of the male rats contained almost no deposited pigment.

Chronic inflammatory lesions were present in the lungs of about one quarter of the animals, without relationship to the treatment. As in the case of animals fed commercial sesamol, a few local hyperplastic lesions were encountered. One male rat on the 1.0% dietary level for 400 days had local thickening of the bladder mucosa like that described in the previous group of animals. There were three benign uterine polyps, one islet adenoma of the pancreas, one small adrenal medullary nodule, and an epithelial tumor of the adrenal cortex which contained many mitotic figures.

Four female rats, one each on dosage levels of 0.016, 0.03, 0.125, and 0.25%, had benign mammary tumors. Three of these were similar, showing a glandular structure in an abundant fibrous stroma. The fourth was predominantly glandular, with a scanty stroma.

One male rat receiving 0.016% sesamol for 576 days had a subcutaneous lipoma and possessed no elements to suggest an origin from mammary gland.

A fibrous tumor of the ovary was quite cellular, and there was sufficient cytological irregularity to suggest malignancy. Much of the surface was sharply defined by a serous covering and there was no extensive invasion of ovarian tissue, so

**Table III. Hyperplastic Changes in Rats Fed Sesamol**

| Type of Lesion | No. of Males | No. of Females | Dietary Level of Sesamol | Days on Diet |
|---|---|---|---|---|
| Lesions in Rats Fed Commercial Sesamol 400 Days | | | | |
| Papillomatous foci in bladder | 1 | | 0.06% | |
| | 2 | | 0.13% | |
| Adenoma of lung | | 1 | 0.03% | |
| Glandular tumor of stomach | | 1 | 1.0% | |
| Uterine polyp | | 1 | 1.0% | |
| Ovarian lipoma | | 1 | 0.5% | |
| Lesions in Rats Fed Pure Sesamol 400–634 Days | | | | |
| Papillomatous foci in bladder | 1 | | 1.0% | 400 |
| Benign uterine polyp | | 1 | 0.03% | 632 |
| | | 1 | 0.06% | 634 |
| | | 1 | 0.25% | 634 |
| Adenoma of pancreas | | 1 | 0.25% | 634 |
| Adrenal medullary nodule | | 1 | 0.5% | 632 |
| Adenoma of adrenal cortex | | 1 | 0.25% | 634 |
| Mammary adenomas | | 1 | 0.016% | 576 |
| | | 1 | 0.03% | 576 |
| | | 1 | 0.125% | 578 |
| | | 1 | 0.25% | 578 |
| Subcutaneous lipoma | 1 | | 0.016% | 576 |
| Fibrosarcoma of ovary | | 1 | 0.5% | 410 |

that the malignancy of the lesion was apparently limited.

The livers and other organs showed no changes which could be ascribed to the sesamol. Table III shows the types and frequency of hyperplastic changes in animals receiving pure sesamol for 400 to 634 days.

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*Received for review January 10, 1958. Accepted May 20, 1958.*


**OFF-FLAVORS IN PROCESSED CROPS**

# Relationship between Pyrrolidonecarboxylic Acid and an Off-Flavor in Beet Puree


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**Pyrrolidonecarboxylic acid, presumably formed from the decomposition of glutamine, was found in off-flavored beet puree at concentrations greater than 200 mg. per 100 grams of puree. In essentially neutral solution, this acid has a decidedly unpleasant flavor, and off-flavor scores for beet puree correlated well with the acid concentration. When pyrrolidonecarboxylic acid is added to beet puree as the ammonium salt, a taste panel could detect significant flavor differences when the concentration is altered by about 50 mg. per 100 grams of puree. Its contribution to off-flavor in processed food is not uncommon.**


RECENTLY attention was drawn to an off-flavor in some garden beet purees that was variously described as bitter, metallic, medicinal, phenolic, and even burnt. The product showed a delayed flavor reaction, which was also described as cumulative and lingering. This off-flavor was not present in the raw beets as received from cold storage but occurred after processing, which included holding the puree at around 200° F. for some time before filling into jars and retorting for 45 minutes at 245° F. No apparent discoloration accompanied the incidence of off-flavor, but the pH was lower and the titratable acidity higher. Silicic acid column chromatography (*14*) of bitter and nonbitter beet purees revealed the presence of formic and pyrrolidonecarboxylic acid (PCA). The formic acid concentration was essentially the same—10 mg. per 100 grams of puree—but 130 mg. of PCA were found in the nonbitter, whereas 230 mg. were present in the off-flavored sample.

The occurrence of PCA in stored and processed biological materials resulting from glutamine degradation has been observed. Ellfolk and Synge (*6*) found that PCA formed in rye grass stored at −20° C. Goodban, Stark, and Owens (*8*) report that in the formation of molasses during the manufacture of beet sugar there is the "well-known conversion of glutamine to PCA." Rice and Pederson (*14*) found PCA in stored tomato juice in concentrations ten times that of freshly processed juice, and suggested that a relation may exist between the formation of PCA and other signs of tomato juice deterioration such as the formation of off-flavors and off-odors. Jodidi (*9*) isolated PCA from Alaska peas oxidized with bichromate.

Glutamine is found in a number of plants processed for food—for example, members of the families Solanaceae, Cruciferae, Umbelliferae, Cucurbitaceae, and Chenopodiaceae (*3, 16*). Specific examples are the potato (*17, 19*) and tomato (*16, 21, 23*), cabbage, carrots and cucumbers (*16*), and beets (*16, 21–23*). One feature of plants