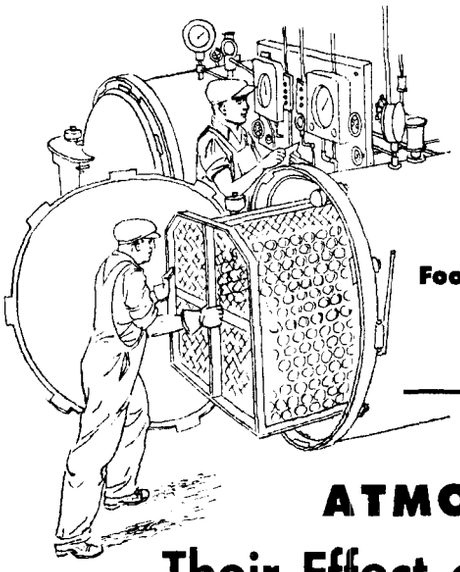


Food Processors Have Odor, Heat, and Isolation Problems

ATMOSPHERIC ODORS
Their Effect on Flavors of Stored Foods

AMOS TURK, PHILIP J. MESSER, and ARTHUR BLASKIEWICZ
Connor Engineering Corp., Danbury, Conn.

Stored food is subject to many types of flavor adulteration by absorption of odorous vapors during cold storage. Such adulteration can be studied by considering the relation between the concentration or odorous intensity of vapors in the storage space and the organoleptically demonstrable changes in flavor of the stored food. Ventilation or methods of air purification can be effective in preventing such flavor adulteration by reducing the average storage vapor concentrations. Food being tested was stored with a variety of odor-contamination sources, in rooms with and without air purification by activated carbon. Flavor differences, evaluated by taste panel comparisons, were statistically very significant. No significant differences were detected between food stored with carbon and an odor source and equivalent food stored alone. The average vapor concentrations were estimated by analysis of carbon sorbates. The results show that significant flavor adulterations of stored food may be caused by storage odors, and that such adulteration is preventable by suitable air purification.

HOWEVER DELICATE and appealing the flavor of a food may be, it is heir to myriads of contaminating effects during cold storage. These potential flavor contaminants include odors from the storage structure itself and its insulation, the organic material which has inevitably been absorbed in the storage structure, and vapors and gases from the stored food itself, especially when parts of the food have begun to decay. In mixed food storage the danger of cross-contamination of flavor is always present, especially from spiced meats, cheeses, and pickles, as well as from small overlooked quantities of decaying meat or rancid fat. The rate of flavor contamination of stored food is a positive function of the concentration of odorous vapors in the atmosphere. For a given set of storage conditions, this vapor concentration may be controlled by supplying the necessary rate of contaminant-free dilution air, according to the equation (*4*)

$$C_w = \frac{1.67\ (10)^4\ G}{Q_d} \qquad (1)$$

where

C_w = concentration of contaminants by weight, pounds per 10^6 cubic feet
G = rate of generation of contaminating vapor, pounds per hour
Q_d = total quantity of pure dilution air, cubic feet per minute

Although ventilation with outdoor air, if sufficiently pure, is a conceivable method of supplying such dilution, it is manifestly prohibitive in cost for storage spaces refrigerated at low temperature because of the great increase it would impose on the refrigeration load. A commercially practical alternative is the purification of the storage air by recirculating it through activated carbon, thus adsorbing its vaporous impurities without affecting its psychrometric properties.

Even when such air purification is used, a portion of the required dilution air, Q_d, is inevitably obtained by infiltration through walls, during door openings, etc., and

$$Q_d = eQ_r + Q_i \qquad (2)$$

Substituting for Q_d in Equation 1,

$$C_w = \frac{1.67\ (10)^4\ G}{eQ_r + Q_i} \qquad (3)$$

where

Q_r = quantity of air purified by carbon adsorption, cubic feet per minute
Q_i = quantity of pure air provided by infiltration, cubic feet per minute
e = efficiency of carbon adsorption (dimensionless)

Previous studies on this subject include work by Van Doren and Bullock (*8*), who showed that air purification by activated carbon protects apples from "storage" flavors, by Woodroof, Thompson, and Cecil (*9*), who showed that air purification prevented absorption of foreign flavors by peanuts, and by Smock and coworkers (*2, 6*), who demonstrated the effectiveness of such purification in controlling food storage odors.

Food storage experiments described in this report show that air purification by activated carbon can effectively reduce atmospheric contamination levels by increments which cause demon-

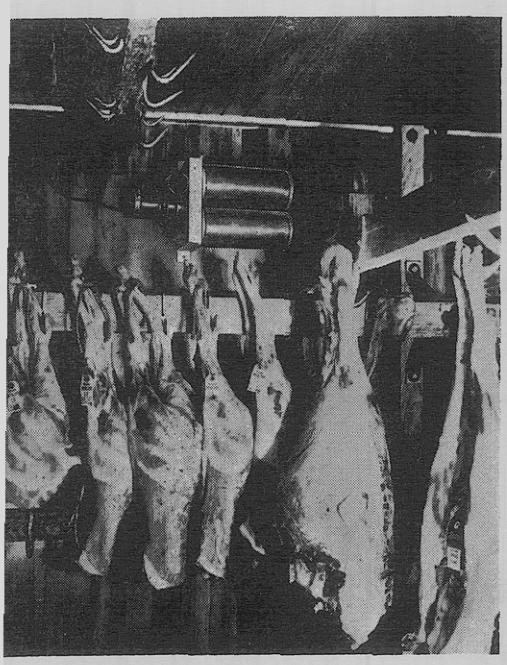


Figure 1. Air purification installation in meat storage

strable improvements in meat and butter flavor.

Experimental Methods

Food storage experiments were carried out in duplicate rooms, each of which was a commercial walk-in cooler of wood construction, provided with gravity coil refrigeration, and of 160 cubic foot capacity. These are referred to as the "carbon" and "control" rooms.

The carbon room was provided with activated carbon air purification. The purification equipment was a commercial unit (Dorex Food Saver, Connor Engineering Corp., Danbury, Conn., installed as shown in Figure 1), consisting of dual perforated activated carbon-filled adsorption canisters assembled integrally with a motor-driven air blower, and provided with an adjustable deflector plate at the air discharge nozzle (Figures 2 and 3). Each canister (Figure 4) contained 1.7 pounds (3100 grams) of granular activated coconut shell carbon, suitable for gas adsorption (Table I), arranged in a uniformly dense cylindrical bed 0.7 inch (1.8 cm.) thick.

The blower circulated air through the two canisters at a rate of 50 cubic feet per minute (1416 liters per minute) corresponding to a linear velocity of about 25 feet per minute (7.62 meters per minute) through the carbon bed. Under such conditions, adsorption efficiency is nearly quantitative before the carbon becomes saturated (*1*, *4*). The control room was provided with identically equivalent air circulation but without activated carbon air purification. Each room contained trays of water so placed that air circulation over the water surface introduced moisture into the space. The temperature in each room was maintained at 36° F. (2.22° C.).

Before a test, each room was cleaned by washing all surfaces with a commercial cleaning compound containing quaternary ammonium salts, rinsing with water, and circulating air through the room overnight at ambient temperature and with door ajar. This procedure effectively deodorized the rooms.

Taste evaluation of stored food was carried out by the panel method, using the duo-trio and triangle tests (*3*). The panel consisted of 10 permanent members and 5 alternates, all selected from a group of office and plant employees previously screened for taste discrimination. Screening was accomplished by measuring the ability of prospective judges to recognize duplicates among a number of dilute solutions of various flavors (*7*)—e.g., beef extracts, vanilla, various fruit flavors, salt, sugar, and distilled water. Acceptable judges were able to recognize at least 18 out of 20 pairs.

The meat taste samples were 1-inch cubes taken from the surface of the stored meat cuts and broiled in an "infrared" broiler without seasoning, for 4 minutes on each of two opposite sides. (The infrared broiler consists simply of an electrical heating element in a partly open housing above the broiling meat, so that no resistance is imposed to the escape of hot fat vapors and fog.) Butter samples were 1 × 1 × 0.25 inch slabs on unsalted soda crackers. Samples (all at body temperature) were presented as follows:

Warm-Up. Sample from carbon room. Mouth rinse.

Test (duo-trio). Sample from carbon room. Mouth rinse.

Sample from carbon or control room. Rinse.
Sample from control or carbon room. Rinse.
} Order random and unknown to observer.

or (triangle).

Carbon Room, Control Room, Carbon Room } Order random and unknown to observer.

Judgment. For duo-trio test. "Which of the last two samples was different from the first sample?"

For triangle test. "Which sample differed from the other two?"

After either test. "Which did you prefer?" "Do you have any comments to make?"

Confidence levels were determined from the critical ratio values calculated according to Peryam and Swartz (*3*):

Table I. Specifications for Activated Carbon Used for Air Purification

Property	Specification
Activity for CCl_4[a]	At least 50%
Retentivity for CCl_4[b]	At least 30%
Apparent density	At least 0.42 gram per ml.
Hardness (ball abrasion)[c]	At least 80%
Mesh distribution	6–14 range (Tyler)

[a] Maximum saturation of carbon, at 20° C. and 760 mm., in air stream equilibrated with CCl_4 at 0° C.

[b] Maximum weight of adsorbed CCl_4 retained by carbon on exposure to pure air at 20° C. and 760 mm.

[c] Per cent of 6–8 mesh carbon which remains on 14-mesh screen after vibrating with 30 steel balls of 0.25- to 0.37-inch diameter per 50 grams of carbon, for 30 minutes.

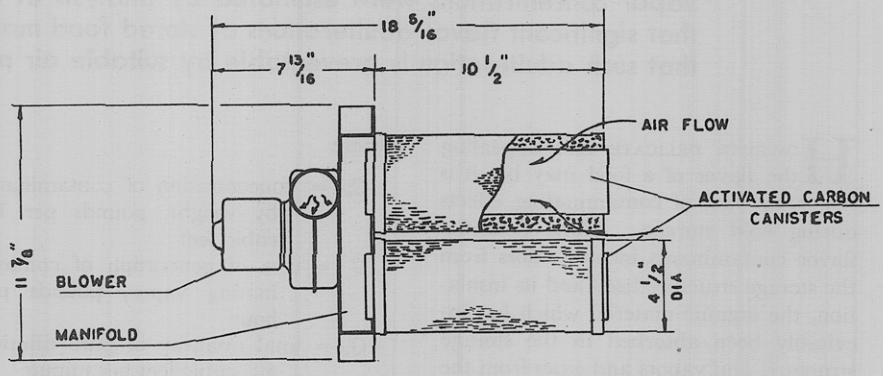
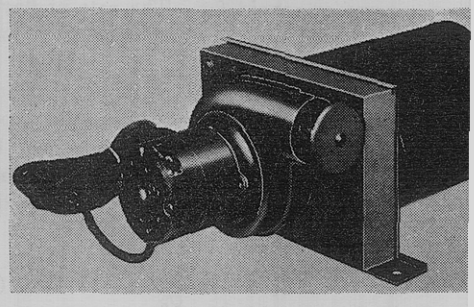


Figure 2. Air purification unit

Figure 3. Air purification unit



$$CR = \frac{(P_{obs.} - P)\sqrt{N}}{P}$$

where

$P_{obs.}$ = observed percentage correct
P = percentage correct expected by chance
= 50 for duo-trio test, or $33^1/_3$ for triangle test
N = total judgments
CR = critical ratio

The area under the normal curve is determined using area tables with the value of the critical ratio as a positive sigma distance. The difference between this area and 0.5, multiplied by 100 and expressed in per cent, is the confidence level.

Average vapor concentrations in the carbon room were measured by determining the degree of saturation of the activated carbon with organic sorbates after the storage period (*5*), and substituting this value in the formula:

$$C_w = \frac{1.67\ (10)^4\ SW}{tQ_r}$$

where

C_w = equilibrium vapor concentration in the carbon room, pounds per 10^6 cubic feet
S = proportionate nonaqueous saturation of carbon
W = weight of carbon, pounds
Q_r = rate of air purification, cubic feet per minute
t = elapsed operating time of air purification equipment, hours

The carbon was analyzed by a steam displacement method (*5*). To convert C_w into volumetric concentration expressed in parts per million by volume, it is necessary to know or assume an average molecular weight of the odorous vapors, and substitute in the formula:

$$C_v = \frac{386\ C_w}{M}$$

Figure 4. Activated carbon canister (cutaway view)

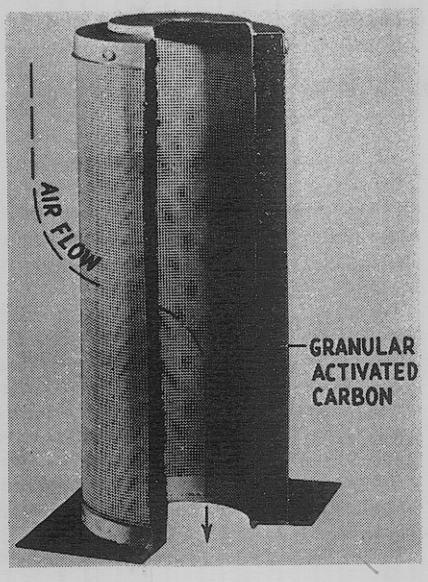


Table II. Effect of Atmospheric Odors on Food Flavor

	Experiment	Taste Test Results: Score[a]	% correct	Confidence limit for significance, %	Taste Preference of Correct Scores	Concn. of Organic Vapors in Carbon Room, Lb./10^6 Cu. Feet
1	Spiced meats + beef	Duo-trio 23v 4 x	85.0	0.01	21 carbon 2 control	0.059
2	Spoiled veal + beef	Duo-trio 14v 7 x	66.7	6.0	14 carbon 0 control	Averaged 0.12
3	Sauerkraut and pickles + beef	Duo-trio 18v 2 x	90.0	0.02	17 carbon 1 control	
4	Spoiled fish + beef	Duo-trio 16v 2 x	89.0	0.05	16 carbon 0 control	
5	Rancid fat + beef	Duo-trio 20v 2 x	90.9	0.006	20 carbon 0 control	0.12
6	Painted surface + beef	Triangle 15v 1 x	93.8	<0.00001	15 carbon 0 control	0.02
7	Onions + butter	Triangle 16v 0 x	100.0	<0.00001	16 carbon 0 control	0.05
8	Melons + butter	Triangle 18v 2 x	90.0	<0.00001	18 carbon 0 control	0.04
9	Repeat 3 with no odor in control	Triangle 5v 15 x	25.0	16 (not significant)	No preferences expressed	
10	Repeat 8 with no odor in control	Triangle 5v 11 x	31.2	41 (not significant)	No preferences expressed	

[a] v = correct.
x = incorrect.

where

C_v = equilibrium vapor concentration in the carbon room, p.p.m.
M = average molecular weight of vapors

Experimental Results

Table II presents the results of the taste tests and air analyses. In the duo-trio test, 50% correct responses would be expected by chance alone if there were no flavor differences between the food in the carbon and control rooms. For the triangle test, chance alone would yield 33.3% correct responses. The quantity and composition of stored foods and contaminants that were used for each experiment are given in the ensuing paragraphs.

Experiment 1. Effect of Odors from Spiced Meats on Beef Flavor. The stored meat consisted of 180 pounds of hindquarter "U. S. Choice" steer meat, hung 3 days after slaughter. The meat was divided into flank, loin, round, and rump cuts. Each of these cuts was then halved and one portion was placed in the carbon room, the other in the control room. The source of odor contamination for each room consisted of three 9 × 13 × 2 inch open glass trays of spiced meat, as follows:

Seven-pound "Margherita Italian brand pork shoulder butt," Cudahy Packing Co., Chicago (smoked and tempered meat).

Seven-pound pork sausage meat (65% lean, 35% fat), with 1 ounce of seasoning per 3 pounds of meat. Seasoning consisted of Morton's sausage seasoning, Morton Salt Co., Chicago, and Dandy Seasoning, Preservaline Manufacturing Co., Flemington, N. J. Seasoning contained pepper, oil of sage, and other spices.

Eight-pound "Italian hot sausage meat," 90% lean pork and veal plus 10% fat; seasoned with hot pepper.

Flavor tests were conducted after 1 week of storage.

Experiment 2. Effect of Odors of Spoiled Meat on Beef Flavor. The stored meat consisted of U. S. Choice steer as described under Experiment 1.

The source of odor contamination was veal from a calf placed under refrigeration 4 days after slaughter. The weight of the clean animal was 66 pounds. The veal was held at 42° F. (5.6° C.) for 6 days, at 60° F. (15.6° C.) for 1 day, and at room temperature for 5 hours. At this point the odor of decomposition was definite but by no means overpowering. This veal was then returned to the box at 36° F. (2.2° C.) to serve as a source of odor contamination of the choice steer beef.

Taste tests were carried out after 6 days' storage.

Experiment 3. Effect of Odors from Sauerkraut and Pickles on Beef Flavor. The stored meat consisted of U. S. Choice steer as in Experiments 1 and 2. The source of odor contamination for each room consisted of one 9 × 13 × 2 inch tray of sauerkraut and two similar trays of dill pickles.

Taste tests were carried out after 4 days of storage.

Experiment 4. Effect of Odors from Spoiled Fish on Beef Flavor. The stored meat consisted of U. S. Choice steer as in the previous experiments. The source of odor contamination consisted of two cod and two haddock exposed to room temperature for 20 hours. Decomposition was advanced at the end of this time. One of each kind of fish was placed in each room as a source of contamination.

Taste tests were conducted after 1 day of storage.

Experiment 5. Effect of Odors from Rancid Fat on Beef Flavor. The stored meat consisted of U. S. Choice steer as in the previous experiments. The source of odor contamination for each room consisted of 10 pounds of rancid scraps of beef fat, taken from a common previously mixed batch.

Taste tests were carried out after 4 days' storage.

Experiment 6. Effect of Paint Odors on Beef Flavor. The stored meat consisted of U. S. Choice steer as in the previous experiments. The source of odor contamination for each room consisted of 6 square feet of freshly painted cardboard surface. An oil paint was used.

Taste tests were carried out after 1 day of storage.

Experiment 7. Effect of Odors from Onions on Butter Flavor. The stored butter consisted of four 4-ounce blocks of salt butter placed in each room. The source of odor contamination for each room consisted of two 9 × 13 × 2 inch trays of sliced onions.

Taste tests were carried out after 1 day of storage.

Experiment 8. Effect of Odors of Cantaloupe on Butter Flavor. The stored butter consisted of 4 ounce blocks as in the previous experiment. The source of odor contamination for each room consisted of three fresh ripe cantaloupes sliced into eighths and placed on glass trays.

Taste tests were carried out after 1 day of storage.

Experiment 9. Experiment 3 was repeated with one variation—no odor source was placed in the control room.

Experiment 10. Experiment 8 was repeated with one variation—no odor source was placed in the control room.

Experiment 11. Storage Odors. Odors in the control room caused by the contaminants used in Experiments 1 to 8 were all moderately intense and objectionable to most observers. The corresponding odor levels in the carbon room were near or below threshold values. A panel test of storage room odors, using the contaminants of Experiment 1, showed an unequivocal recognition of the odor in the control room.

Procedure

Screen air purification and blower units
Blindfold subject
Enter carbon room
Leave
Remove blindfold
Enter control or carbon room } Order random and unknown to observer
Enter carbon or control room } Order random and unknown to observer
Judge which room subject smelled when blindfolded

Results

Correct judgments, 20
Incorrect judgments, 0
Per cent correct, 100
Confidence limit for significance, 0,002%

Discussion

The taste scores and their statistical analysis presented in Table II show highly significant differences in meat and butter flavor due to removal of atmospheric odors. The sources of odor contamination selected were intended to duplicate contaminants likely to be present in commercial food storage, where different varieties of food may be stored together, unnoticed food scraps may decompose in inaccessible parts of the room, and, in rare instances, a new or used storage box may be painted or oiled. Odors from such sources will contaminate food flavor to a degree that depends on the prevailing odor intensity in the storage space and the duration of food storage in the odorous atmosphere. Food flavor contamination by atmospheric odors is not practically significant when the odor concentration is below threshold. Thus the positive removal of odor in a food storage space is, for all practical purposes, equivalent to the effective elimination of flavor adulteration by air-borne organic vapors. This was shown by the results of experiments 9 and 10, in which the panel members failed to distinguish between food stored under air purification in a contaminated room and equivalent food stored alone in a clean room.

Taste preferences were overwhelmingly in favor of the uncontaminated foods. Descriptions of the contaminated samples included "flat," "off-taste," "less flavor," "lack of flavor," "meaty," "different," "gamey," "sharp," "odd," "did not like it"—expressions which also, incidentally, reflect the poverty of language for describing chemical senses. Only in experiments 3 and 7 were some members sufficiently acute to describe the butter as "oniony" and the meat as "sour."

Literature Cited

(1) Dole, M., and Klotz, I. M., *Ind. Eng. Chem.*, **38,** 1289 (1946).
(2) Gross, C. R., and Smock, R. M., *Refrig. Eng.*, **50,** 535 (December 1945).
(3) Peryam, D. R., and Swartz, V. W., *Food Technol.*, **4,** 390 (1950).
(4) Sleik, H., and Turk, A., "Air Conservation Engineering," 2nd ed., Chap. VIII, Connor Engineering Corp., Danbury, Conn., 1953.
(5) Turk, A., Sleik, H., and Messer, P. J., *Am. Ind. Hyg. Assoc. Quart.*, **13,** 23 (1952).
(6) Uota, M., and Smock, R. M., *Refrig. Eng.*, **54,** 256 (March 1948).
(7) U. S. Dept. Agr., *Agr. Inform. Bull.* **34,** 15–16 (1951).
(8) Van Doren, A., and Bullock, R. M., *Proc. Am. Soc. Hort. Sci.*, **55,** 239 (1950).
(9) Woodroof, J. G., Thompson, H. H., and Cecil, S. R., *Food Ind.*, **21,** 16 (1949).

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COTTONSEED MEALS

Influence of Processing on Protein Values

BARNETT SURE with the assistance of LESLIE EASTERLING, JOY DOWELL, and MARY CRUDUP
University of Arkansas, Fayetteville, Ark.

COTTONSEED MEAL has been used as a protein concentrate for farm animals for many years with varying degrees of success. The amount that can be fed to young calves, poultry, and swine is limited because of the gossypol occurring in the resin glands (*1*) of cottonseed, which is not completely converted to the nontoxic bound gossypol (*2, 3, 8, 10*) during processing. The effect of processing conditions on the chemical properties of cottonseed meal was studied and reported by Haddon, Thurber, and associates (*5*).

In 1950 the Protein and Carbohydrate Division of the Southern Regional Research Laboratories, under the direction of Aaron M. Altschul, began a comprehensive study with several state experiment stations to investigate the nutritive value of cottonseed meals, prepared by special processes which would ensure a minimum content of free gossypol and thus render them nontoxic to chickens and swine when fed in liberal quantities. The department of agricultural chemistry of the University of Arkansas undertook the study of the influence of processing on the protein values of cottonseed meals. For this work three types of cottonseed meals were prepared by the Southern Regional Research Laboratories:

Solvent-Extracted Cottonseed Meal. Flaked cottonseed meals were extracted with hexane to remove the lipides and then with butanone (methyl ethyl ketone) containing 3% water to remove the major portion of the gossypol. The extracted meats were heated only sufficiently to remove the residual solvent. The meal contained 55.1% protein and 0.015% free gossypol.

Screw-Press Meal. Meal 1 was cooked