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Review of Literature on Chicken Flavor and Report of Isolation of Several New Chicken Flavor Components from Aqueous Cooked Chicken Broth

Richard A. Wilson* and Ira Katz

Fifty liters of broth from 80 lb of stewing chickens cooked at 90°C under atmospheric pressure was filtered, subjected to continuous centrifugation to remove fat, and the volatiles were vacuum stripped. The distillate was saturated with sodium chloride and extracted with methylene chloride. The concentrated volatiles, analyzed by combined gas–liquid chromatography/mass spectrometry, consisted of 68 components, of which 47 were identified by their mass spectra and relative retention indices. The majority were saturated and unsaturated alcohols, aldehydes, and ketones, of which those reported for the first time in chicken were 1-octanol, 2-methyl-3-buten-2-ol, 1-penten-3-ol, 3-penten-2-ol, 1-octen-3-ol, linalool, *trans*-2-octenol, α-terpineol, 4-hexen-3-one, 2,4-nonadienal, and piperonal. Suggested explanations for their occurrence are offered.

During the last 20 yr many investigators, employing varied approaches, have identified a total of 178 components in cooked and raw chicken. These are summarized in Table I.

It was felt that a more complete picture of the flavor volatiles might be obtained by examining chicken broth from which most of the fat had been removed after cooking. In this way it was hoped to increase the probability of identifying the more water-soluble components.

International Flavors and Fragrances, Inc., 1515 Highway No. 36, Union Beach, New Jersey 07735.

EXPERIMENTAL

Preparation of Broth. Eighty pounds of locally procured, eviscerated, stewing chickens were stored at −28°C in poly-

Table I. Chemical Compounds Identified in Chicken as Reported in the Literature

Compound	References
Hydrocarbons	
3-Penten-1-yne[a]	Nonaka *et al.* (1967)
Ethane[b,c]	Minor *et al.* (1965b)
Propane[b,c]	Minor *et al.* (1965b)
n-Heptane[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
2-Methylheptane[a]	Hobson-Frohock (1970)
n-Octane[a]	Hobson-Frohock (1970)
4-Octyne[a]	Nonaka *et al.* (1967)
n-Nonane[a]	Hobson-Frohock (1970)
n-Decane[a]	Hobson-Frohock (1970)
n-Undecane[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
n-Dodecane[a]	Hobson-Frohock (1970)
n-Tridecane[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
3-Methyltridecane[a]	Hobson-Frohock (1970)
n-Tetradecane[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
n-Pentadecane[a]	Hobson-Frohock (1970)
n-Hexadecane[a]	Hobson-Frohock (1970)
n-Heptadecane[a]	Hobson-Frohock (1970)
Methylcyclohexane[a]	Hobson-Frohock (1970)
d-Limonene[a]	Nonaka *et al.* (1967)
Aromatic hydrocarbons	
Benzene[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
Toluene[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
o-Xylene[a]	Nonaka *et al.* (1967)
m-Xylene[a]	Nonaka *et al.* (1967)
p-Xylene[a]	Nonaka *et al.* (1967)
n-Propylbenzene[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
1,2,4-Trimethylbenzene[a]	Nonaka *et al.* (1967)
1,3,5-Trimethylbenzene[a]	Hobson-Frohock (1970)
1,2-Diethylbenzene[a]	Hobson-Frohock (1970)
Ethyldimethylbenzene[a]	Hobson-Frohock (1970)
n-Butylbenzene[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
n-Amylbenzene[a]	Nonaka *et al.* (1967)
n-Hexylbenzene[a]	Nonaka *et al.* (1967)
Ethylphenylbutane[a]	Hobson-Frohock (1970)
n-Heptylbenzene[a]	Nonaka *et al.* (1967)
Naphthalene[a]	Hobson-Frohock (1970)
Furans	
Tetrahydrofuran[d]	Grey and Shrimpton (1967b)
Furan[d]	Grey and Shrimpton (1967b)
2-Methylfuran[a]	Nonaka *et al.* (1967)
2-Ethylfuran[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
2-*n*-Propylfuran[a]	Nonaka *et al.* (1967)
2-*n*-Butylfuran[a]	Nonaka *et al.* (1967)
2-*n*-Amylfuran[a]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
2-*n*-Hexylfuran[a]	Nonaka *et al.* (1967)
2-*n*-Heptylfuran[a]	Nonaka *et al.* (1967)
Alcohols	
Methanol[b,c,d]	Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Minor *et al.* (1965b)
Ethanol[b,c,d]	Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Minor *et al.* (1965b)
n-Butanol[a,b]	Minor *et al.* (1965b) Hobson-Frohock (1970)
Isobutanol[b]	Minor *et al.* (1965b)
Esters	
n-Pentanol[a,c]	Minor *et al.* (1965b) Hobson-Frohock (1970)
Isopentanol[c]	Minor *et al.* (1965b)
n-Hexanol[a,c]	Minor *et al.* (1965b) Hobson-Frohock (1970)
n-Heptanol[b,c]	Minor *et al.* (1965b)
2-Propyn-1-ol (propargyl alcohol)[a]	Nonaka *et al.* (1967)
1-Methyl-2,3-indanediol[a]	Nonaka *et al.* (1967)
3-Hexanol[a]	Hobson-Frohock (1970)
2-Methyl-2-propanol[a]	Hobson-Frohock (1970)
2-Methyl-2-butanol[a]	Hobson-Frohock (1970)
Methyl formate[b]	Minor *et al.* (1965b)
Methyl acetate or ethyl formate[a]	Nonaka *et al.* (1967)
Methyl 2,4-pentadienoate[a]	Nonaka *et al.* (1967)
Ketones	
Acetone[a,b,c,d]	Pippen *et al.* (1958) Pippen and Nonaka (1960) Minor *et al.* (1965a) Minor *et al.* (1965b) Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Hobson-Frohock (1970)
Diacetyl[a,b,c,d,e]	Pippen *et al.* (1958) Pippen and Nonaka (1960) Pippen *et al.* (1960) Minor *et al.* (1965a) Minor *et al.* (1965b) Minor *et al.* (1966) Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Hobson-Frohock (1970)
Acetoin[a,b,c,d,e]	Pippen and Nonaka (1960) Pippen *et al.* (1960) Minor *et al.* (1965b) Minor *et al.* (1966)
2-Butanone[a,d]	Pippen and Nonaka (1960) Minor *et al.* (1965a) Nonaka *et al.* (1967) Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Hobson-Frohock (1970)
3-Buten-2-one[a]	Nonaka *et al.* (1967)
2-Pentanone[a]	Pippen and Nonaka (1960) Nonaka *et al.* (1967) Hobson-Frohock (1970)
3-Pentanone[d]	Grey and Shrimpton (1967a) Grey and Shrimpton (1967b)
3-Methyl-2-butanone[d]	Grey and Shrimpton (1967a) Grey and Shrimpton (1967b)
1-Penten-3-one[a]	Nonaka *et al.* (1967)
2-Hexanone[d]	Grey and Shrimpton (1967a) Grey and Shrimpton (1967b)
2-Heptanone[a,b,c]	Pippen and Nonaka (1960) Minor *et al.* (1965b) Nonaka *et al.* (1967)
2-Octanone[a]	Nonaka *et al.* (1967)
3-Octanone[a]	Nonaka *et al.* (1967)
2-Methyl-6-heptanone[a]	Nonaka *et al.* (1967)
2-Nonanone[a]	Nonaka *et al.* (1967)
2-Decanone[a]	Nonaka *et al.* (1967)
5-Undecanone[a]	Nonaka *et al.* (1967)
2,4-Pentanedione[b,c]	Minor *et al.* (1965b)
2,3-Pentanedione[a]	Hobson-Frohock (1970)

Table I. *(Continued)*

Compound	References
Ethers	
Ethyl ether[d]	Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
Fatty acids	
Acetic[f]	Annison *et al.* (1968)
Propionic[f]	Annison *et al.* (1968)
Isobutyric[f]	Annison *et al.* (1968)
n-Butyric[f]	Annison *et al.* (1968)
Isovaleric[f]	Annison *et al.* (1968)
2-Methylbutyric[f]	Annison *et al.* (1968)
Aldehydes	
Acetaldehyde[a,b,c,d]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Minor *et al.* (1965a); Minor *et al.* (1965b); Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
Propionaldehyde[a,d]	Pippen *et al.* (1958); Minor *et al.* (1965a); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
n-Butyraldehyde[a,d]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Minor *et al.* (1965a); Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b); Hobson-Frohock (1970)
n-Valeraldehyde[a,b,d]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Minor *et al.* (1965a); Minor *et al.* (1965b); Nonaka *et al.* (1967); Grey and Shrimpton (1967b); Hobson-Frohock (1970)
2-Methylbutyraldehyde[a]	Nonaka *et al.* (1967); Hobson-Frohock (1970)
3-Methylbutyraldehyde[a]	Hobson-Frohock (1970)
n-Hexanal[a,b,c,d]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Minor *et al.* (1965a); Minor *et al.* (1965b); Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b); Hobson-Frohock (1970)
2-Methylvaleraldehyde[d]	Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
4-Methylvaleraldehyde[d]	Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
n-Heptanal[a,b,c]	Pippen and Nonaka (1960); Minor *et al.* (1965b); Nonaka *et al.* (1967); Hobson-Frohock (1970)
5-Methylhexanal[d]	Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
Aldehydes *(Continued)*	
n-Octanal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Minor *et al.* (1965a); Nonaka *et al.* (1967); Hobson-Frohock (1970)
n-Nonanal[a]	Pippen *et al.* (1958)
n-Decanal[a]	Hobson-Frohock (1970)
n-Undecanal[a]	Hobson-Frohock (1970)
n-Tridecanal[a]	Nonaka *et al.* (1967)
n-Hexadecanal[a]	Pippen and Nonaka (1960)
n-Octadecanal[a]	Pippen and Nonaka (1960)
Acrolein[d]	Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
trans-2-Butenal[a]	Pippen and Nonaka (1960)
trans-2-Pentenal[a]	Pippen *et al.* (1958)
trans-2-Hexenal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960)
trans-2-Heptenal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960); Nonaka *et al.* (1967)
trans-2-Octenal[a]	Pippen and Nonaka (1960)
trans-2-Nonenal[a]	Pippen and Nonaka (1960)
trans-2-Decenal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960)
trans-2-Undecenal[a]	Pippen *et al.* (1958)
trans-2,*trans*-4-Heptadienal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960)
trans-2,*trans*-4-Decadienal[a]	Pippen *et al.* (1958); Pippen and Nonaka (1960)
Benzaldehyde[a]	Hobson-Frohock (1970)
n-Propylbenzaldehyde[a]	Nonaka *et al.* (1967)
Phenylpropionaldehyde[a]	Nonaka *et al.* (1967)
Sulfur compounds	
Methanethiol[a,d]	Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
Ethanethiol[a,c,d]	Minor *et al.* (1965b); Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
n-Propanethiol[b,c,d]	Minor *et al.* (1965b); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
n-Butanethiol[d]	Grey and Shrimpton (1967b)
n-Hexanethiol[b,c]	Minor *et al.* (1965b)
1,2-Ethanedithiol[a]	Nonaka *et al.* (1967)
Methyl sulfide[b,c,d]	Minor *et al.* (1965b); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b)
Methyl ethyl sulfide[c]	Minor *et al.* (1965b)
Methyl isopropyl sulfide[c]	Minor *et al.* (1965b)
Ethyl sulfide[b,c]	Minor *et al.* (1965b)
Ethyl *n*-propyl sulfide[b,c]	Minor *et al.* (1965b)
n-Propyl sulfide[b,c]	Minor *et al.* (1965b)
Methyl disulfide[a,c,d,e]	Minor *et al.* (1965b); Nonaka *et al.* (1967); Grey and Shrimpton (1967a); Grey and Shrimpton (1967b); Hobson-Frohock (1970)

Table I. (*Continued*)

Compound	References
Ethyl disulfide[b,c]	Minor *et al.* (1965b) Nonaka *et al.* (1967) Grey and Shrimpton (1967a) Grey and Shrimpton (1967b)
2-Methylthiophene[a,b,c]	Nonaka *et al.* (1967) Hobson-Frohock (1970)
Carbonyl sulfide[a]	Nonaka *et al.* (1967)
s-Trithiane[c]	Minor *et al.* (1965b)
Dimethyl trisulfide[c]	Swoboda (1970)
Inorganics	
Ammonia[a]	Pippen and Eyring (1957)
Hydrogen sulfide[a,c,d,e]	Pippen and Eyring (1957) Pippen and Nonaka (1960) Grey and Shrimpton (1967a) Grey and Shrimpton (1967b) Parr and Levett (1969) Pippen and Mecchi (1969) Pippen *et al.* (1969)
Carbon disulfide[a]	Nonaka *et al.* (1967)
Amino acids and peptides	
Alanine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Arginine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Aspartic acid[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Cysteine[b,c]	Mecchi and Pippen (1964) Koehler and Jacobson (1967)
Cystine[b,c]	Mecchi and Pippen (1964) Minor *et al.* (1966)
Glutamic acid[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Glutathione[b,c]	Mecchi and Pippen (1964) Minor *et al.* (1966) Parr and Levett (1969)
Glycine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Histidine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Isoleucine[d,e]	Miller and Dawson (1965)
Isoleucine–leucine[b,c]	Koehler and Jacobson (1967)
Leucine[d,e]	Miller and Dawson (1965)
Lysine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Methionine[b,c,d,e]	Mecchi and Pippen (1964) Miller and Dawson (1965) Minor *et al.* (1966) Koehler and Jacobson (1967)
Phenylalanine[b,d]	Miller and Dawson (1965)
Proline[b,d]	Miller and Dawson (1965)
Serine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Taurine[b,c,d,e]	Mecchi and Pippen (1964) Miller and Dawson (1965) Koehler and Jacobson (1967)
Threonine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Tyrosine[b,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Tryptophan[b,c]	Koehler and Jacobson (1967)
Valine[b,c,d,e]	Miller and Dawson (1965) Koehler and Jacobson (1967)
Sugars	
Glucose[b,c]	Koehler and Jacobson (1967)
Fructose[b,c]	Koehler and Jacobson (1967)
Ribose[b,c]	Koehler and Jacobson (1967)
Inositol[b,c]	Koehler and Jacobson (1967)
Miscellaneous	
Creatine[b,c]	Minor *et al.* (1966)
Creatinine[b,c]	Minor *et al.* (1966)
Inosinic acid[b,c]	Minor *et al.* (1966)
Lactic acid[b,c]	Koehler and Jacobson (1967)
Hypoxanthine[b,c]	Koehler and Jacobson (1967)
Inosine[b,c]	Koehler and Jacobson (1967)
Inosine monophosphate[b,c]	Koehler and Jacobson (1967)
Guanosine monophosphate[b,c]	Koehler and Jacobson (1967)
Amines	
Methylamine[b,c]	Minor *et al.* (1965b)
Ethanolamine[c]	Minor *et al.* (1965b)
Chlorinated hydrocarbons	
Chloroform[a]	Hobson-Frohock (1970)
Trichloroethylene[a]	Hobson-Frohock (1970)
Chlorobenzene[a]	Hobson-Frohock (1970)
Dichlorobenzene[a]	Hobson-Frohock (1970)
Tetrachlorobenzene[a]	Hobson-Frohock (1970)

[a] Found in cooked mixed flesh. [b] Found in cooked light flesh. [c] Found in cooked dark flesh. [d] Found in raw light flesh. [e] Found in raw dark flesh. [f] Found in the caecum.

ethylene bags until used. Then they were thawed at room temperature for 12 hr, chopped into small pieces, bones, skin and flesh inclusive, and cooked with agitation in 20 l. of distilled water in a stainless steel steam-jacketed vessel at approximately 90°C for 1 hr. The broth was cooled in approximately 50 min to 40°C by circulating water at 15°C through the jacket. Solids were removed from the broth by filtration through 2.5 mesh and then 20 mesh stainless steel screens. The fat was removed by continuous centrifugation in a Westphalia separator. Immediately after centrifugation the aqueous phase was chilled rapidly to approximately 5°C by the addition of polyethylene bags containing ice; the chilled broth was stored at that temperature.

The chicken solids were cooked a second time and the broth was processed as already described; combination of the aqueous phases resulted in approximately 50 l. of broth.

Concentration of Volatiles. The volatiles were stripped from the broth under vacuum in an all-glass apparatus

Table II. Chemical Compounds Identified in Chicken

	I_E on unknown[a]	I_E on known[a]	Previously reported
Alcohols			
Saturated			
n-Butanol	5.00	5.00	×
n-Pentanol	6.07	6.08	×
n-Hexanol	7.13	7.15	×
n-Heptanol	8.16	8.19	×
n-Octanol	9.19	9.24	
Unsaturated			
2-Methyl-3-buten-2-o	3.80	3.79	
1-Penten-3-ol	5.11	5.10	
3-Penten-2-ol	5.21	5.29	
1-Octen-3-ol	8.12	8.18	
Linalool	9.07	9.00	
trans-2-Octenol	9.75	9.73	
α-Terpineol	10.43	10.49	
Aromatic			
Benzyl alcohol[b]	Not determined	Not determined	
1-Phenyl-1-propanol[b]	Not determined	Not determined	
Phenylethyl alcohol[b]	Not determined	Not determined	
Acids			
Phenol[b]	Not determined	Not determined	
p-Cresol[b]	Not determined	Not determined	
Heterocyclics			
n-Pentylfuran[b]	6.00	6.00	×
2-Methylpyrazine[b]	6.31	6.34	
Lactones			
γ-Octalactone[b]	Not determined	Not determined	
Ketones			
Saturated			
Acetone	1.00	0.98	×
2-Butanone	2.15	2.21	×
2-Heptanone	5.47	5.47	×
Unsaturated			
4-Hexen-3-one	5.53	5.54	
3-Buten-2-one	2.85	2.83	×
Aldehydes			
Saturated			
n-Valeraldehyde	3.29	3.29	×
n-Hexanal	4.48	4.44	×
n-Heptanal	5.46	5.47	×
n-Octanal	6.49	6.52	×
n-Nonanal	7.57	7.62	×
Monounsaturated			
2-Methylcrotonaldehyde	Not determined	Not determined	
trans-2-Hexenal	5.80	5.85	×
trans-2-Heptenal	6.83	6.83	×
trans-2-Octenal	7.87	7.87	×
trans-2-Nonenal	8.92	9.00	×
trans-2-Decenal	9.95	9.97	×
trans-2-Undecenal	11.02	11.10	×
Diunsaturated			
2,4-Heptadienal	8.48	8.45	×
2,4-Nonadienal	10.49	10.64	
2,4-Decadienal	11.60	11.69	×
Aromatic			
Benzaldehyde	8.75	8.81	×
Piperonal	15.41	15.42	
Hydrocarbons			
p-Xylene[b]	5.00	5.08	×
o-Xylene[b]	5.46	5.57	×
Limonene	5.61	5.70	×
Naphthalene[b]	10.81	10.95	×
Methylnaphthalene[b]	Not determined	Not determined	

[a] I_E's were determined on a 200-ft × 0.03-in. Carbowax 20M open tubular column. [b] Tentative identification.

essentially the same as that described by Bidmead and Welti (1960). The system was partially evacuated and approximately 14 l. of broth was aspirated into the distilling chamber through a Teflon-lined hose. The pressure was decreased to approximately 70–90 mm and low pressure steam was introduced into the heat exchangers located in the side arms until distillation commenced at a temperature of approximately 40°C. By controlling the vacuum and steam rate, distillation was maintained at approximately 1 l./hr.

When 5 l. of distillate had been collected in the wet ice trap, the distillation was stopped, the residue discarded, a fresh charge of 14 l. introduced, and the process repeated. By this method, approximately 15 l. of distillate was collected. The distillates were combined and stored at 5°C until the distillation step was completed. The distillate was divided into 1500-ml portions; each was saturated with sodium chloride (approximately 300 g/l.) and extracted three times with 150 ml of distilled methylene chloride. The combined extracts were dried over anhydrous sodium sulfate and concentrated in a Kuderna-Danish evaporative concentrator equipped with a 1-m reflux column packed with 7 × 7 glass Raschig rings. A 1:10 takeoff to reflux ratio was employed. The volume after concentration was approximately 5 ml, which was further reduced to 0.5 ml by allowing the sample to remain open to the air at room temperature overnight in a test tube. A brown pungent oil resulted.

Analyses. Analyses were made by gas–liquid chromatography (glc) and glc coupled with mass spectrometry. Glc analyses were performed on a Hewlett-Packard 5750 gas–liquid chromatograph with the following columns being employed: a $^1/_8$-in. o.d. × 50-ft Carbowax 20M Hi-Pak, a 0.03-in. bore × 200-ft Carbowax 20M open tubular column, and a 0.03-in. bore × 525-ft Carbowax 20M open tubular column. For glc/mass spectrometry, a 0.03-in. × 200-ft Carbowax 20M open tubular column coupled to an Hitachi RMU-6E mass spectrometer with a Biemann separator was utilized employing a mass spectrometer: flame detector split ratio of 5:1, a source temperature of 160°C, and an ionizing potential of 70 eV. Mass spectral identifications were confirmed wherever possible by calculation of glc retention indices relative to a series of ethyl esters of normal alkanoic carboxylic acids (van den Dool and Kratz, 1963) and comparison with data on known components.

RESULTS AND DISCUSSION

Table II contains the components identified in the volatile fraction of the aqueous phase of cooked chicken broth. Identifications that are described as tentative are due to either weak mass spectra or the inability to determine accurately the glc retention index of the peak. The three diunsaturated aldehydes are believed to have the trans,trans configuration, although we are not certain because the configuration of the known samples on which the retention indices were run is uncertain.

Compounds which are reported for the first time in chicken include *n*-octanol, 2-methyl-3-buten-2-ol, 1-penten-3-ol, 3-penten-2-ol, 1-octen-3-ol, linalool, *trans*-2-octenol, α-terpineol, 4-hexen-3-one, 2,4-nonadienal, and piperonal.

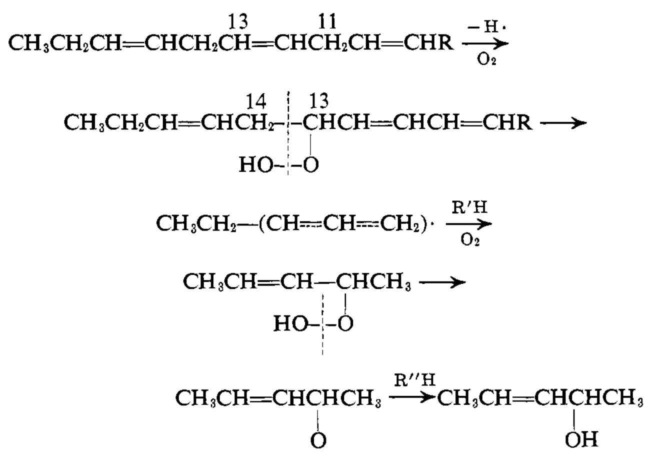
If we speculate as to the source of these chemicals in chicken we find that, with the exception of 3-penten-2-ol, *trans*-2-octenol, and 4-hexen-3-one, all have been reported in natural products.

n-Octanol occurs in many fruits and berries, tea, fermented beverages, red meats, and dairy products (Weurman, 1969). Stark and Forss suggested in 1966 that the probable precursor in oxidized butter was 10-hydroperoxy octadec-8-enoate from the autoxidation of oleate.

2-Methyl-3-buten-2-ol has been reported in fruits, tea, and hop oil (Weurman, 1969). On reporting its occurrence in Valencia orange, Schultz *et al.* (1964) proposed that it arose through the decarboxylation and partial dehydration of mevalonic acid. However, partial dehydration of a polyol should preferentially occur at a tertiary hydroxyl yielding an isopentenol and, indeed, this product was isolated while studying mevalonate conversion to cholesterol in yeast (Bloch, 1959).

1-Penten-3-ol has been found in buttermilk, oxidized soybean oil, several fruits, and tea (Weurman, 1969). Its occurrence as a butter off-flavor has been explained by autoxidation of linolenate *via* the formation of the 13-hydroperoxide (Stark *et al.*, 1967).

Similarly, 3-penten-2-ol might result from autoxidation of linolenic acid by catalytic abstraction of hydrogen from C_{11}, hydroperoxide formation at C_{13}, cleavage of the C_{13}–C_{14} bond, and oxidation at C_2 of the resultant 5-carbon fragment followed by reduction:



where R = $-(CH_2)_7COOH$

1-Octen-3-ol is a common component of natural products, having been reported in oxidized soybean oil, dairy products, coffee, cocoa, tea, and berries (Weurman, 1969). Various precursors have been proposed for its formation, including the hemiacetal of 11-linoleate free radical (Hoffmann, 1962), C_{10} hydroperoxide of 10-linoleate free radical (Stark and Forss, 1964), and C_{12} hydroperoxide of 12-arachidonate free radical (Stark and Forss, 1964).

2,4-Nonadienal, which has been reported in oxidized soybean oil and in beef and pork fat (Weurman, 1969) and in oxidized skim milk (Forss *et al.*, 1955), was found to be one of the products of the autoxidation of a linoleic acid model system (Hoffmann, 1962). It could not be predicted on theoretical grounds but was explained by hydroperoxide formation at other than an α-methylene group, by unknown precursors, or by secondary oxidation of fragmented free radicals from aldehyde decomposition.

The biogenesis of alk-2-en-1-ols has not been extensively investigated because they have not often been reported in nature. Those occurrences that have been reported have been explained by oxytropic rearrangement of the corresponding alk-1-en-3-ols (Forss, 1967) by a mechanism such as that proposed by Braude (1950).

Linalool and α-terpineol are common constituents of essential oils (Weurman, 1969). Their biosynthesis in plants from mevalonic acid *via* acyclic monoterpenoid pyrophosphates is well documented (Moss, 1970). However, this metabolic pathway has been demonstrated outside the plant kingdom only in ants (Happ and Meinwald, 1965). A much more likely explanation is systemic introduction from the feed.

Piperonal, 3,4-methylenedioxybenzaldehyde, also known as heliotropine, has a more limited distribution in nature, having been reported only in a few flower oils (Guenther and Althausen, 1949) and in some varieties of vanilla bean (Bohnsack, 1965). Lacking sufficient information to suggest its formation *in vivo*, we feel that it quite likely was ingested and isolated unchanged.

We have as yet been unable to rationalize satisfactorily the occurrence of 4-hexen-3-one. However, since closely related compounds have already been explained through fatty acid autoxidation, we feel that this mechanism might also apply to this compound. For instance, 1-octen-3-one was isolated from autoxidized model systems of linoleic and arachidonic acids; 1-penten-3-one was found in autoxidized linolenic acid; and 3-octen-2-one came from arachidonic acid (Badings, 1970).

SUMMARY

A literature search covering the past 20 yr revealed that 178 chemical compounds have been identified in cooked and raw chicken. This report includes 11 new compounds identified for the first time in cooked chicken. Possible explanations for their occurrence in the isolate are discussed either as they have been described in the literature or as suggested by the authors. Seven can be rationalized as autoxidation products of either oleic, linoleic, linolenic, or arachidonic acids, all of which have been shown to be present in chicken lipids (Marion and Woodroof, 1965). Three are explained on systemic grounds, and one possibly as a metabolite.

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Qualitative Analysis of the Essential Oil of Cassia (*Cinnamomum cassia* Blume)

Roelof ter Heide

Cassia oil (*Cinnamomum cassia* Blume) has been analyzed by means of gas chromatography of fractions obtained by extraction of the oil with sodium bisulfite, sodium hydroxide, and sodium carbonate. The individual components were identified by mass, infrared, and nmr spectral methods. Thirty-five components were identified in the oil. Twenty-three of them have not previously been reported to be present in cassia oil. Except for some of the acids, all constituents found are benzene derivatives, of which 11 components are substituted in the ortho position.

Oil of cassia is the volatile oil distilled from the leaves and twigs originating from *Cinnamomum cassia* Blume, which is cultivated mainly in the southeastern part of the People's Republic of China in the provinces of Kwangsi and Kwangtung. Cassia oil is appreciated for its cinnamon-like flavor, an effect which is based on the presence of the main component of the oil, *i.e.*, cinnamaldehyde. However, it is impossible to achieve cassia flavor with cinnamaldehyde alone, so that it was interesting to know which components were present besides cinnamaldehyde. Our investigations concern the analysis of crude commercial cassia oil directly imported from the People's Republic of China. Most of the components were identified on the basis of identity of their infrared spectra, mass spectra, and retention data with those of authentic reference compounds. Only a few components of the essential oil of cassia have been reported. The presence of cinnamaldehyde and of 2-methoxycinnamaldehyde in cassia oil is already known for a long time (Bertagnini, 1853; Rochleder *et al.*, 1850, 1854). The latter compound was originally named cassia–stearoptene by Rochleder *et al.* (1850, 1854), but Bertram and Kürsten (1895) proved it to be 2-methoxycinnamaldehyde. The results of the analysis of the nonaldehydic fraction of cassia oil, in which cinnamyl acetate was found to be the major component, possibly accompanied by 3-phenylpropyl acetate, have been reported (*Ber. Schimmel*, 1889). A small amount of free cinnamic acid was also reported. Dodge (1918) and Dodge and Sherndal (1915) isolated salicylaldehyde, benzaldehyde, and 2-methoxybenzaldehyde, and further reported the presence of coumarin, cinnamic acid, benzoic acid, and salicylic acid in the alkali-soluble part of the oil.

Chowdhury and Williams (1964) described an infrared method to distinguish the leaf and twig oil from the bark oil by determination of the content of 2-methoxycinnamaldehyde. The bark oil contains less of this aldehyde.

von Schantz (1962) analyzed cassia oil by thin-layer chromatography and detected cinnamaldehyde, cinnamyl acetate, and eugenol. Paris and Godon (1963), however, did not find eugenol in their sample of cassia oil. These authors and Richter (1965) obtained a positive reaction for cinnamaldehyde by using paper and thin-layer chromatography. Betts (1965) reported the absence of eugenol in cassia bark oil. Montes (1963) applied gas chromatography for the separation of cassia oil constituents and found a number of components, including eugenol and salicylaldehyde.

The latter compound could not be traced by Wellendorf (1963).

EXPERIMENTAL

Reference Substances. Authentic samples of components were obtained from reliable commercial sources or synthesized by well established methods. They were purified by gas chromatography before use.

Operating Conditions. The gas chromatographic analysis was performed on a modified Becker instrument with a flame ionization detector. Three columns were employed. The first column (3 m × 0.25-in. o.d., stainless steel) was packed with diethyleneglycolsuccinate on 80–100 mesh acid-washed Embacel support in the weight ratio 20:80.

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