conditions of oilseed protein products; (3) flavor of the oilseed protein; (4) color of oilseed protein product; (5) gluten strength of wheat flour; and (6) type of bread baking system used; influence the amount of oilseed protein product used in bread formulation. Modifications such as changes in baking absorption, mixing time, and use of emulsifiers are necessary to produce an optimum loaf of bread. At present, it is possible to bake bread with 50% more protein and improved amino acid profile compared to white-pan bread without any significant changes in its flavor and baking properties.

NEW RICE VARIETIES: THEIR SPECIFIC COOKING, PROCESSING, AND COMPOSITIONAL CHARACTERISTICS

B. D. Webb, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, Beaumont, Texas 77706

New varieties of rice must constantly be developed and released for commercial production to keep abreast of the needs and requirements of the U.S. rice industry. In recent years a number of improved varieties representing the traditional bland-flavored (nonwaxy), long-, medium-, and short-grain types have gone into commercial production. In addition to the traditional types, varieties having more specific end-use properties have been developed. These include improved varieties (1) with an aromatic (nutty-like) flavor, (2) characterized by an all waxy (glutinous) endosperm, (3) developed for specific industrial and brewing applications, and (4) suitable for both table and industrial uses.

The new varieties differ widely with respect to composition, cooking, eating, and processing behavior. These differences are defined by a number of analytical and physical parameters which collectively serve as indicators of specific rice qualities. Parameters include amylose/amylopectin ratio, gelatinization temperature, amylographic viscosity, protein and amino acid levels, parboil–canning stability, cookability with malt enzymes, cooked volume, and texture measurements. The parameters of the new varieties and their relationship to specific rice cooking, processing, and nutritive properties will be discussed.

REVIEWS

Oxazoles and Oxazolines in Foods

Joseph A. Maga

The occurrence of oxazoles and oxazolines in various food and model systems is reviewed relative to the specific systems from which these compounds have been isolated. In addition, the organoleptic properties of these compounds were discussed as well as their formation pathways.

To date, numerous classes of compounds have been identified in foods, and their potential organoleptic significance has been the basis for extensive research and review. One such class of compounds consists of oxazoles and oxazolines, which are heterocyclic compounds containing both nitrogen and oxygen. Their occurrence in our food supply was reported less than a decade ago. However, only approximately a dozen investigators have reported upon them with most of these just listing the compounds as being present.

Thus, it is the primary objective of this review to summarize the brief history of these compounds relative to their food occurrences and sensory properties in the hopes of stimulating researchers to continue to initiate investigations in this interesting area of flavor chemistry.

FOOD OCCURRENCES

Most organoleptically important flavor compounds have been identified in a wide variety of foods, but in the case of oxazoles and oxazolines their presence to date has only been reported in three food systems, namely coffee, cocoa, and meat products.

Coffee. The reports of Stoffelsma and Pypker (1968) and Stoffelsma et al. (1968) were apparently the first identifying an oxazole as naturally occurring in a food. The compound identified was 5-acetyl-2-methyloxazole. More recently, Vitzthum and Werkhoff (1974) identified another 20 oxazoles in coffee. The oxazoles identified to date are summarized in Table I. Interestingly oxazolines have not been identified in coffee to date.

Table I. Oxazoles Identified in Coffee

2,4-dimethyloxazole[a]	5-ethyl-2-methyloxazole[a]
2,5-dimethyloxazole[a]	2,4,5-trimethyloxazole[a]
4,5-dimethyloxazole[a]	2,5-dimethyl-4-ethyloxazole[a]
2-ethyloxazole[a]	2,4-dimethyl-5-ethyloxazole[a]
4-ethyloxazole[a]	4,5-dimethyl-2-ethyloxazole[a]
5-ethyloxazole[a]	5-methyl-2-propyloxazole[a]
2-ethyl-5-methyloxazole[a]	4,5-dimethyl-2-propyloxazole[a]
4-ethyl-2-methyloxazole[a]	5-acetyl-2-methyloxazole[b,c]
5-ethyl-4-methyloxazole[a]	5-acetyl-2,4-dimethyloxazole[a]
2-ethyl-4-methyloxazole[a]	2-methylbenzooxazole[a]
4-ethyl-5-methyloxazole[a]	

[a] Vitzthum and Werkoff (1974). [b] Stoffelsma and Pypker (1968). [c] Stoffelsma et al. (1968).

Cocoa. Vitzthum et al. (1975) are the only group to date reporting upon the occurrence of oxazoles in cocoa. They have identified 2,5-dimethyl-, 4,5-dimethyl-, 2,4,5-trimethyl-, and 5-methyl-2-propyloxazoles in the volatile basic fraction of roasted cocoa. Again no oxazolines were reported.

Meat Products. As seen in Table II, both oxazoles and oxazolines have been identified in several meat products. It is of interest to note that these compounds have only been reported in heated meat systems and that only a small number of such compounds have been identified.

Colorado State University, Department of Food Science and Nutrition, Fort Collins, Colorado 80523.

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Table II. Oxazoles and Oxazolines Identified in Meats

meat system	compound	reference
boiled beef	2,4,5-trimethyl-3-oxazoline	Chang et al. (1968)
		Hirai et al. (1973)
		Mussinan et al. (1976)
		Chang et al. (1977)
		Chang and Peterson (1977)
	2,4-dimethyl-3-oxazoline	Mussinan et al. (1976)
	2,4-dimethyl-5-ethyl-3-oxazoline	Mussinan et al. (1976)
	2,5-dimethyl-4-ethyl-3-oxazoline	Mussinan et al. (1976)
	2,4,5-trimethyloxazole	Chang et al. (1977)
canned beef stew	2,4,5-trimethyloxazole	Peterson et al. (1975)
		Chang and Peterson (1977)
	2,4,5-trimethyl-3-oxazoline	Peterson et al. (1975)
		Chang and Peterson (1977)
cooked pork liver	2,4,5-trimethyloxazole	Mussinan and Walradt (1974)

Table III. Reported Sensory Properties of Oxazoles and Oxazolines

compound	flavor description	reference
2,4-dimethyloxazole	nutty, sweet	Shibamoto (1977)
2,5-dimethyl-3-oxazoline	nutty, vegetable	Mussinan et al. (1976)
2,4,5-trimethyloxazole	nutty, sweet, green	Mussinan et al. (1976)
2,4,5-trimethyl-3-oxazoline	woody, musty, green	Mussinan et al. (1976)
2,5-dimethyl-4-ethyl-3-oxazoline	nutty, sweet, green, woody	Mussinan et al. (1976)
2,4-dimethyl-5-ethyl-3-oxazoline	nutty, sweet, vegetable	Mussinan et al. (1976)

Table IV. Flavor Thresholds of Various Oxazoles and Oxazolines [Mussinan et al. (1976)]

compound	threshold
2,5-dimethyl-3-oxazoline	1.0 ppm
2,4,5-trimethyloxazole	5.0 ppb
2,4,5-trimethyl-3-oxazoline	1.0 ppm
2,5-dimethyl-4-ethyl-3-oxazoline	0.5 ppm
2,4-dimethyl-5-ethyl-3-oxazoline	1.0 ppm

Mussinan et al. (1976) only identified oxazolines but no oxazoles in their beef systems. In their study the system was heated at either 163 or 182 °C. Oxazolines were identified at both temperatures but relative concentration differences were not mentioned. In the case of canned beef stew, Peterson et al. (1975) reported that the relative gas chromatographic peak size associated with 2,4,5-trimethyloxazole was medium whereas that for 2,4,5-trimethyl-3-oxazoline was large. With boiled beef, Hirai et al. (1973) reported the peak size area of 2,4,5-trimethyl-3-oxazoline to be extra large. To date, the above represent the only published indication as to the relative amounts of these compounds that are present in foods.

ORGANOLEPTIC PROPERTIES

Few sensory properties have been reported for oxazoles and oxazolines, thus making it rather easy to summarize the data in Table III. However, it is quite apparent from Table III that these compounds possess some unique organoleptic properties that should have food flavoring application. This fact can further be appreciated by considering the few threshold data that have been published. Mussinan et al. (1976) evaluated the potency of the compounds listed in Table IV and, as can be seen, most compounds had a flavor threshold in the neighborhood of 1 ppm. However, it is interesting to note that only one oxazole, namely 2,4,5-trimethyloxazole, was evaluated and it had a measured flavor threshold in water of 5 ppb. It would be of interest to determine if other oxazoles had lower thresholds than their corresponding oxazolines.

FORMATION PATHWAYS

The synthesis of alkyloxazoles has been reported by Vitzthum and Werkhoff (1974) to be rather straightforward and involves the reaction of α-halocarbonyls with thioamides. Likewise, alkyloxazolines can be synthesized as reported by Mussinan et al. (1976) whereby ammonia is reacted with an appropriate aldehyde and hydroxyketone.

Relative to their formation in actual food systems, little work has been reported. Shibamoto (1977) reacted furfural, hydrogen sulfide, and ammonia and identified 2,4-dimethyloxazole as one of the 17 reaction products. Thus, he concluded that furfural had fragmented into smaller carbon units which in turn could react to form the compound in question. Mussinan et al. (1976) have suggested that 2,4,5-trimethyl-3-oxazoline can form in heated meat systems by the thermal interaction and rearrangement of the compounds ammonia, acetaldehyde, and acetoin, all of which have been reported to be present in cooked meat.

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