OFF-FLAVORS IN FOODS: 2. GENETICS AND DIETS

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Abstract

The acceptance of food is based on many factors. Of those factors, genetics of animals and feed or diets are singnificantly related to off-flavors of fresh and processed foods. Two animal species, ovine and swine, are often having specific-species related flavor. Genetic causing off-flavor of lamb is mutton flavor or "soo" odor and swine sex taint flavor is "sex odor". Constituents of animal feed are capable of causing off-flavors in animal food products by transmittion of feed ingredients and microbial contaminants in feed ingredients to the eggs or milk and/or the flesh of animals. The most well known is the muddy-earthy flavor of fish and shell fish due to the actinomycetes and blue green algae containing geosmin and related compounds.

It is obvious that genetics and diets have a very strong influence on the flavor of both plants and animals. The differences in flavor between the numerous varieties of plant foods are acceptable. However, consumer do not accept differences in meat flavor due to either genetic or diet differences between animals. Usually the consumer expect all meats of the same species to taste the same.

Genetics

Two animal species in which genetics plays an important role in producing an off-flavor (OF) are swine and ovine. The lean portion is believed to contribute a basic meaty flavor while the fat portion contributes the characteristic species flavor (Reineccius, 1979).

Mutton flavor

The mature ovine is considered to have an unpleasant odor being described "sweaty-sour" in nature or "Soo" odor in Chinese (Wong, 1975). The important source of this OF has been identified as 4-methyl-octanoic and 4-methylnonanoic acid.

This species-related flavors of mutton is closely associated with some volatiles, medium chain-length fatty acids of which several methyl-branched members are highly singnifficant. The formation mechanism of the most important lamb and mutton flavor, 4-methyloctanoic acid, is shown in Figure 1 (Lindsay, 1985). Ruminal fermentations yield acetate, propionate, but most fatty acids are biosyn- thesized from acetate, which yields nonbranched chains. Some methyl branching occurs routinely because of the presence of propionate. Dietary and other factors may enhance propionate concentrations in the rumen, greater methyl branching occurs.

Swine sex odor

The undesirable odor of heated fat from an entire uncastrated adult male pig (boar) has been a problem facing the swine industry for many years. This odor was called "boar odor" untill it was found to occur in barrows, gilts and sows as well as in boars and therefore, suggested the name of "sex odor" for this off-odor (Reineccius, 1979). "Sex odor" occurs in about 75% of boars and about 5% in barrows, gilts

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and sowns. This odor becomes distinctive in the carcasses of older boars (appoximately 2 years and upwards), but it is not usually detectable in the carcasses of young boars slaughtered at 200 1b liveweight (Patterson, 1968).

Two compounds are primarily responsible for the swine sex odor, 5a-androst-16-en-3-one (16-androstenes) (Figure 2) which has a urinous aroma (Patterson, 1968; Lindsay, 1985), and 5a-androst-16-en-3a-ol, which has a musklike aroma (Lindsay, 1985). These steroid compounds are particularly offensive to some individuals, especially women, and yet some individuals are genetically odor blind to them. 3a-Hydroxy-5a-androst-16-ene was later found to involve in causing the sex odor (Reineccius, 1979).

The testis of the mature boar produces large amounts of the odorous 16-androstenes which accumulate in the submaxillary salivary gland before secretion into saliva to act as pheromones. Due to their lipophilic nature, the 16-androstenes also accumulate in the body fat and are primarily responsible for boar taint in the carcasses of mature boars. Booth et al. (1986) reported that determination of 16-androstenes in the submaxillary gland might offer an alternative method for assessing boar taint since they found a close relationship between 16-androstene in the submaxillay gland and 5a-androstene in adipose tissue.

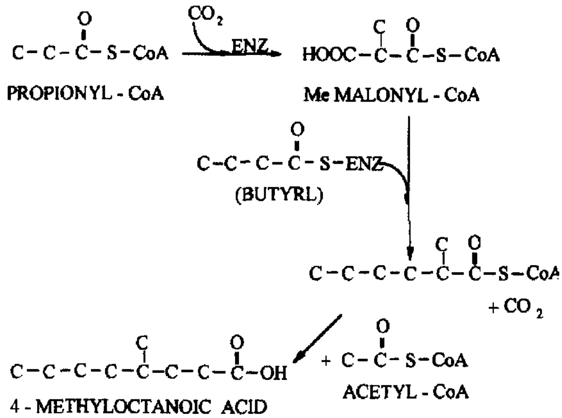

Fig. 1. Ruminant biosynthesis of methyl-branched medium-chain fatty acids.
Source: *Lindsay (1985).*

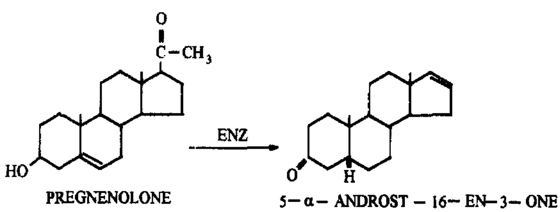

Fig. 2. Formation of steroid compound resposible for the urinous aroma associated with the swine sex odor defect of pork.
Source: *Lindsay (1985) and Patterson (1968).*

Chicken flavor

The distinctive flavors of poultry have also been the subject of many studies. Although lipid oxidation appears to yield the character impact compounds for chicken, other parameters such as diet, sex, age, processing conditions, and storage are emphasized. The carbonyls c4-decanal, t2, c5-undecadienal, and t2, c4, t7-tridecatriental reportedly may contribute the characteristic flavor of stewed chicken, and they are derived from linoleic and arachidonic acids. The directed lipid oxidations may occur in poultry, leading to species-related flavors (Lindsay, 1985).

Age and sex are found to affect on flavor of the poultry. The greater flavor intensity is obseved from the older than the younger birds, especially in 6-14 weeks old even though their muscle has similar chemical composition but the older has higher concentration (Fry et al., 1958; Minor et al., 1965). Sex seems to be a factor in the carbonyl production in turkey. Male turkeys have higher concentration of carbonyl compounds, especially 3 to 8 more unsaturated aldehydes produced by female (MacNiel and Dimick, 1970).

Fish flavor

In the past, consumers have equated seafood quality with a product exhibiting few undesirable flavor attributes. Today, flavor quality is becoming important to consumers with their increased experience and sophistication in seafood consumption. A new seafood nomenclature system, based on sensory or edibility characteristics of fish including flavor, is under development. Prell and Sawyer (1988) studied flavor profiles of 17 species of North Altantic fish. Species were characterized for aroma and flavor total intensity, amplitude order and intensity of character notes, and aftertaste. Fish species were grouped according to similarities in their characteristics. Four distinct groups of fish were characterized by using flavor profiles including 1) less than moderate total flavor intensity with a shellfish note; (2) less than moderate total flavor intensity with an earthy note; 3) a moderate flavor intensity with fish oil, gamey and sour note; 4) high total flavor intensity with fish oil, sour, and stronger gamey notes.

Sawyer et al. (1988) evaluated sensory attributes of 18 common Atlantic species. Thirteen sensory attributes were identified including texture and flavor characteristics. The flavor characteristics were shellfish, fish oil, briny/salty, gamey, and sour. These flavor characteristics may be very useful for species identification.

Diets

Flavors of animal foods may arise from the animal feed by passage of the substances from feed into meat or milk. This transfer may be via digestive system and blood stream.

Poultry

Off-flavors in poultry due to diet occur very readily. Musty taint in eggs and broilers is known to be due to the presence of chloroanisoles in the air. Bemelmans and Noever de Brauw (1974) also found chloroanisoles in poultry feed. Thus, the feed may also contribute musty OF to the poultry meat.

Off-flavor may also enter poultry meat via the diet from the consumption of highly unsaturated fats. Crawford and Kretsch (1976) reported that "fishy" flavor was developed in roasted turkeys fed a basal diet supplemented with beef fat or tuna oil. From the GC-MS identification of the compounds found in the volatiles of roasted turkey, they found 41 compounds that were of fishy flavor is likely an oxidative process which occurs during cooking.

When rapeseed meal is fed as a source of protein the eggs of certain hens become tainted with trimethylamine (TMA) which imparts a "fishy" or "crabby" odor. Rapeseed is very commonly used as a protein supplement in laying hen rations in some country such as Canada. Rapeseed contains sufficient amount of (-) 2-hydroxy-3-butenyl glucosinolate (progoitrin) which can be converted to 5-vinyl oxazolidine (goitrin) in the gastrointestinal tract by the action of bacterial thioglucosidase (myrosinase). The goitrin is found to suppress TMA oxidation by inhibition of TMA oxidase (Pearson et al., 1983). Pearson et al. (1983) reported that TMA in the eggs was above its threshold even the laying hens fed with low glucosinolate rapeseed meals. Sinapine (the choline ester of 4-hydroxy-3, 5-dimethoxycinnamic acid) is an important source of TMA which is released when its choline component is broken down. However, Goh et al. (1983) reported that in diet containing a constant amount of sinapine, it was free oxazolidinethione (goitrin), and not total glucosinolate, in the diet that increased the TMA content of the eggs and the incidence of fishy eggs.

Fish and Shellfish

Fish are very susceptible to absorbing chemicals from their environment resulting in objectionable OF. The problems may occur due to fish consuming foods which result in taints or due to absorption of pollution from industry waste or natural off-odors in the fish's environment.

A "muddy-earthy" flavor in fish has been found associated with the presence of microorganisms species of actinomycetes and blue green algae in water environments. The undesirable flavor is absorbed by fish through the digestive system and the gill membranes (Lovell and Sackey, 1973). The compounds responsible for OF in fish and shellfish are geosmin, 2-exo-hydroxy-2-methylbornane, 2 methylisoborneol, and mucidone with geosmin the major cause of muddy flavor (Flick, Jr. et al., 1980). The known structures of these compounds are presented in Figure 3. Hsieh et al. (1988) confirmed that geosmin was the major compound responsible for the objectionable muddy or musty-earthy OF in Louisiana brackish water clams (*Rangia cuneata*). Geosmin (trans-1, 10-dimethyl-trans-9-decalol) was positively identified based on gas chromatographic retention time, electron ionization mass spectra, and odor characteristics. Confirmation was based on analysis of authentic geosmin under experimental conditions comparable to those of clam samples.

Effects of feed ingredients on flavor quality of farm-raised fish were studied by Johnson (1989). Flavor descriptors including OF were established for fresh and frozen, stored fish. OF descriptors included green vagetable/grassy, egg/sulfury, geosmin/dry musty, MIB/wet musty (MIB = 2-methylisoborneol), Geosmin

Mucidone
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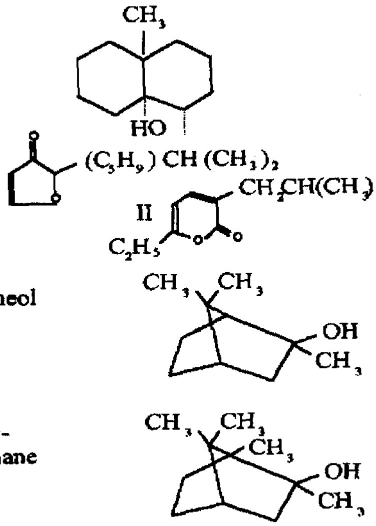
2-methylisoborneol

2-exo-hydroxy-
2-methylbornane



*Most Probable Structure.

Fig. 3. Compounds responsible for undesirable flavor in fish and shellfish.
Source: *Flick, Jr. et al. (1980).*

decaying vegetation, carboardy and fishy. Cultures of streptomycetes and algae in feed ingredients and environment can produce either MIB or geosmin or both. The extraordinary abundance of OF-producing organisms within a pond is due to the excess amounts of nutrients present in the water causing surplus nitrogen and phosphorus resulting in extensive blooms of algae (Johnson, 1989).

Meat

Among cattle, it appears that flavor desirability of beef is rather strongly dependent upon what the animal has been fed (grain vs forage) and/or how long grain has been the major component of animal's diet. Beef from forage and pasture diet usually has less desirable flavor than beef from grain-finished diet (Bowling et al., 1977; Melton, 1983; Bailey et al., 1980: Joseph, 1986).

A wide variety of grasses appear to cause beef to have less desirable flavor than that produced by grain-containing diets. These grasses, as compiled by Melton (1983), include bromegrass, bluestem, cool-and warm-season grass, blue grass, clover, fescue, orchardgrass, flint hills grass, native range grass, forage sorghum, oats, rye, ryegrass, millet or coastal bermuda grass and sudan grass.

Bowling et al. (1977) compared beef carcasses feed on forage-finished and grain-finished and reported that the grain-finished beef was more desirable in flavor than forage-finished beef. Bailey et al. (1980) reported that steaks and roasts from grain fed cattle were more acceptable than those from fescue pasture fed cattle. From GC-MS studies, the compounds associated with "grassy" or "oily" flavor were identified as octadecane, C5-C10 aldehydes, 2, 4-decadienal and *s*-decalactone. These compounds are derived from saturated fatty acids and some hydrocarbons in the grass leaves. Joseph (1986) reported that ryegrass or clover fed beef had more intensity of "grassy" flavor and had higher concentrations of volatile flavor compounds than corn fed beef. The compounds associated with "grassy" flavor were identified as hexanal, heptanal, nonanal, 2-decenal, 2-nonenal, hexadecane, heptadecane and isoprenoid hydrocarbons such as phy-1-ene, phy-2-ene, neophytadiene, phytane and phytol.

Like cattle, diet of lamb is found to influence the flavor of its meat. Most of the lamb flavor research which relates to diet has dealt with an OF which is undesirable. "Mutton" flavor is believed to be a more intense characteristic lamb flavor (Field et al., 1983). Park et al. (1972) reported that lambs raised on legumes lucerne *(Medicago sativa)* was found to have more intense "sharp" and "sickly" flavor than those raised on phalaris pasture. However, Field et al. (1983) found that lamb fed on grasses produced stronger flavor than that fed on silage or grain. Studies the flavors of lambs fed on different pastures; clover, lucerne, lotus, and ryegrass and those fed on corn, Suzuki (1985) reported that lambs finished on forage pastures produced higher intensity of "lamby-sheepy" odor than those fed on corn. The marker compounds of meat from forage-fed lambs were 2, 3-octanedione, 3-hydroxy-2-octanone, and diterpenoids and the compounds causing "lamby-sheepy" odor were phy-2-one, heptanal, branched hydrocarbon, and a-pinene.

Milk

Off-flavors in milk caused by the transfer of substances from cow's feed into the milk while it is in the udder are called transmitted flavors. They include flavors commonly described as feed and weed flavor (Bassette et al., 1986; Shipe et al., 1978).

Feed flavors of milk are undesirable flavors in freshly drawn milk produced by cows that consume certain type of feed. When cows are allowed to consume feed within 2 to 4 hours before milking, the milk produced will have a "silage-like" OF. Many such feed can be fed immediately after milking and withheld 4 to 5 hours before milking without producing a feed flavor in the milk (Reineccius, 1979).

The flavors are described as "sweetish" when cow fed on corn silage, slightly grassy and fishy when cow fed on rye pasture and described as "soda" or "alkaline" OF when cow fed on alfalfa-bromegrass pasture. The major compounds contributing to the feed odors are methyl sulfide, trans-2-hexenal, 3-hexenal, and 3-hexenol (Bassette et al., 1986).

Numerous species of weeds when consumed by the cow impart serious OFs to milk. One of the most common and readily recognized weed flavors is that caused by the consumption of wild garlic. The OF is described as garlic flavor (Bassette et al., 1986). The flavor components from some weeds are relatively nonvolatile and are not exhausted rapidly from the cows body via the lungs. Therefore, they may affect the flavor of the milk until they are excreted or otherwise metabolized, a process which may take as long as 12 hours (Shipe, 1978).

In summary, off-flavors of foods can certainly be caused by genetics and diets. The most important genetic-causing OF are mutton flavor or "soo" odor, and swine sex odor or "sex odor". The first one is the odor of ruminant animals, the later is the odor of nonruminant animals. Compounds responsible for these odors are 4-methyloctanoic acid and 5-a-androst-16-en-3-one, respectively. Species, age and sex of fish could produce objectional flavor due to differences in majority and composition of fats and carbonyl compounds.

The same compound such as chloroanisoles found in air and feed can cause musty taint in eggs and broilers. Also tuna-oil fed and TMA fed poultry could produce fishy flavor in eggs and poultry meat.

Muddy-earthy flavor of fish and shellfish mainly derives from bluegreen algae and actinomycetes contaminated in feed ingredients and water. Meat from ruminant animal fed on forage and pasture diet appears to be less desirable due to grassy flavor and higher intensity of "lamby-sheepy" odor for lambs. Diets of cow could transmit undesirable flavor to milk. Milk OF may be described as "silage-like", "soda" or "grassy and fishy" when cow fed on pasture.

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