# Use of Poultry Collagen Coating and Antioxidants as Flavor Protection for Cat Foods Made with Rendered Poultry Fat

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## ABSTRACT

Poultry skins and rendered poultry fat are by-products produced in excess at rendering plants. The use of low value by-products such as poultry collagen, from poultry skins, and fat to improve flavor and quality in dry pet food could be economically attractive. This study examined a poultry collagen coating as a protective barrier against oxidation in dry cat food made with rendered poultry fat. Collagen was extracted from chicken skins, dissolved in an acidic solution, applied to dry cat food and dried to form a surface film. Six treatments were examined: kibble, kibble with fat, kibble with collagen, kibble with fat and collagen, kibble with fat, BHA/BHT and collagen and kibble with fat, tocopherol and collagen. There were two storage conditions: 'jungle condition' (42°C and 83% relative humidity) and 'ambient condition' (21°C and 51% relative humidity). In 'jungle conditions', thiobarbituric acid reactive substances (TBARS) was measured over an eight-day period at day 0, 2, 4, 6, and 8. In 'ambient conditions', TBARS was measured over a thirty-day period at day 0, 7, 14, 21, and 30. Water activity and moisture contents were measured. There were significantly higher TBARS ($P<0.05$) for the control kibble at both storage conditions. There was significantly higher fat percentage ($P<0.05$) in all treatments with the additional fat coatings. Fatty acid compositions showed slight changes during storage. There were some changes in the aroma profile of the kibble with fat treatment having musty, moldy and plastic aromas at both storage conditions. The volatile aromas might be an indication of oxidation in the poultry fat.

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# CHAPTER 1

# INTRODUCTION

Over 46 billion pounds of perishable materials generated annually by livestock, poultry, and food processing are recycled by the rendering industry. In 1996, the production value of rendered products in the U.S. was approximately $3.0 billion. These materials are processed into valuable ingredients for soaps, paints, cosmetics, toothpaste, pharmaceuticals and lubricants. The majority of the rendered products are sold to the feed industry in the form of high-energy fats and high-quality protein ingredients (Anon., 2003). Animal protein meals are excellent sources of calcium, phosphorus, protein and essential amino acids (Anon., 2003).

Rendered products are utilized extensively in the formulation of pet foods. The pet food industry is very competitive. In 2001, 55% of all American households were home to at least one pet cat or dog, with a total estimate of 110 million cats and dogs requiring feed (Dominy, 2002). The pet food market is estimated at annual sales of more than $8 billion, with global market estimates of $30.5 billion. Product sales are continuing to increase each year as are the number of pet food manufacturers and brands. Dry pet foods historically have been available commercially and make up approximately 48% of all pet foods produced and marketed.

The growth of the pet food market has resulted in increased amounts of rendered product being purchased by the pet food industry. Billions of pounds of rendered animal fat and protein are purchased to meet the increased production demand of pet food. Mechanically deboned beef is the primary rendered product purchased by the pet food industry, followed by deboned chicken (BeMiller and Whistler, 1996). Poultry by-

products meals, typically 65-70% protein (Cowell et al., 2000), are widely used in dry cat food as a source of protein and fat (BeMiller and Whistler, 1996).

Dry cat food provides the following nutrients: protein, carbohydrates, fats, vitamins and water, which are required to help provide cats with a healthy diet. All of these nutrients are crucial to the growth, development and adult stages of a animal's life cycle. The majority of dry cat food is comprised of the following gross nutritional contents according to Association of American Feed Control Officials (AAFCO, 2003).

**Table 1. Nutritional Profile of Cat Food According to AAFCO, Based on Dry Matter**

| | |
|---|---|
| Crude Protein (minimum amount) | 30.0% |
| Crude Fat (minimum amount) | 10.0% |
| Crude Fiber (maximum amount) | <5.0% |
| Moisture (maximum amount) | 10.0% |

(AAFCO, 2003)

Proteins are the building blocks of the body. Cats use various combinations of approximately 20 amino acids to create proteins. The amino acids can be essential, which means, they must come from the diet, or nonessential which means they can be manufactured by the body. Fats supply essential fatty acids. Fats are needed in feline diets to transport fat-soluble vitamins throughout the body. Also water is vital for life processes is and a nutritional necessity. Therefore, proteins, carbohydrates and fats supply the energy that is needed for life-sustaining processes.

The addition of animal fats to the feed rations increases the energy value and improves the palatability of the overall product (Anon., 2003). The selection and quality of a fat are very important. For example, low quality fat might cause some palatability issues in the pet food. The type of animal fat chosen for a particular type of pet food depends on its impact on palatability of the final product (Cowell et al., 2000). In dry pet

food, the main source of fat is either beef tallow or other types of animal (poultry or pork) fat and, sometimes, vegetable oils. The type of fat added to the dry food depends on different factors. While flavor and nutritional contributions are important, price and oxidative stability are perhaps the most important factors (BeMiller and Whistler, 1996). Fat is the most expensive ingredient, when fat quality is considered (BeMiller and Whistler, 1996).

Poultry fats, with somewhat high amounts of polyunsaturated fatty acids, are more susceptible to oxidation than beef tallow and lard (Cross et al., 1987). Pet food produced with poultry fat has higher oxidation rates than a comparable formulation produced with beef tallow (Lin et al., 1998). After processing, oxidation reactions must be controlled to avoid a decrease in palatability of dry pet food (Deffenbaugh, 2000). In the pet food industry, the manufacturer has a goal to produce a product that is nutritionally complete and balanced and that a pet will enjoy eating. For this to occur, the food must be very pleasing to the palate (Kvamme, 2000). Good palatability can be sometimes described as having a pleasing aroma, an appealing taste and good mouthfeel (Kvamme, 2000; Trivedi et al., 2000; Schanus et al., 2000). Palatability must be assured throughout the shelf life of the product, which can be long in dry cat food. Normally, dry cat food has a shelf-life of 12-18 months. Changes in flavor and aroma profiles can negatively impact palatability (Deffenbaugh, 2000). Palatability of dry cat food is a concept that includes different factors interacting with a common goal to assure success and a competitive advantage (Deffenbaugh, 2000).

Animal panels are used to test the palatability of pet food. Extensive attempts are made to train the animals. Palatability testing involves five steps that must be followed. A

pre-test training involves teaching the animals to eat from two different bowls without spilling the contents of one into another. Then environmental controls are established. The assignment of test animals into subpopulations for test panels then must be made. A testing process must be developed, followed by validation of the results as the final step (Trivedi et al., 2000). Maintaining a laboratory animal colony and the intensive training makes palatability testing of pet food very expensive, difficult and time consuming for companies. Palatability testing is performed on a new pet food product or when significant modifications, such as ingredients, have been made in the composition of the pet food. Modifications such as utilizing inexpensive ingredients or low-cost suppliers can reduce the cost of pet food. However, ingredients can have an effect on the overall sensory characteristic of dry pet foods and decreased palatability due to reformulation should be avoided.

Most pet foods have unique sensory profiles for flavor, aroma and textural attributes that contribute to the palatability of the product. Dry pet foods usually require performance, including palatability, be maintained for at least a year after production and packaging to allow for distribution, storage and sales (Kvamme, 2000). During storage, attributes of pet food can either decrease, increase or perhaps even stay the same. Autoxidation of lipids during shelf life increases negative attributes and decreases positive attributes (Kvamme, 2000).

Palatability may be improved through control of degradation processes and contribution of positive flavor components by using coating systems. The volatile flavor profile of a dry cat food has a direct relationship to its palatability performance (Kvamme, 2000). Semi-moist and dry pet foods are more susceptible to quality

degradation related to changes in moisture. Semi-moist and dry pet-foods with low water activities do not require as high an oxygen barrier as moist products. The low availability of water in these products limits the rate of oxidation and lowers bacteria growth rates. However, market needs for longer shelf life and transition from synthetic to natural antioxidants has led to a need to reduce moisture contents for dry pet foods to as low as 6% (Coelho, 2001).

A nutraceutical is an additive, such as vitamins A and E, that increase the nutritional content of a food. However, natural antioxidants, such as vitamin E, can degrade and be lost during the oxidation process. Therefore, the shelf life of pet food is determined on the basis of how fast the incorporated nutraceutical is lost; this can be affected by a few factors such as temperature and moisture (Bell, 2001). Stability testing is used to evaluate the effects of temperature, moisture, oxygen, pH and composition on the stability of the petfood with nutraceuticals (Bell, 2001). Nutraceuticals are tested using an accelerated shelf life test, where the use of high temperatures and water activities cause an accelerated effect. Accelerated testing saves time and money, but the disadvantages are that water activity, pH, reactive solubility and physical states all change as the temperature increases (Bell, 2001).

Selection of formulation, processing and packaging conditions that control degradation of nutrients and can contribute or maintain positive palatability profiles is important. Use of rendered poultry fat, a low-value by-product of the poultry industry with important nutritional and flavor components, would add value to the pet food product. However, control of oxidative mechanisms for reactions must be in place to maintain palatability for the intended distribution and storage periods.

**RESEARCH OBJECTIVES:**

The objective of this project was to evaluate the use of collagen coatings as flavor protection in dry pet food made with rendered poultry fat. Since poultry fat contains high amounts of polyunsaturated fatty acids, it can very easily oxidize especially during temperature abused conditions. Futhermore, poultry fats are physically softer, have lower melting points, and are more susceptible to oxidation (Cross et al., 1987). Poultry fat may increase the palatability of the dry pet food.

The first objective of this study was to identify volatile compounds in dry cat food (poultry fat added) produced mainly by lipid oxidation and possibly protein and carbohydrate degradation under specific storage conditions. The second objective of this study was to compare the effect of antioxidants and chelators with and without collagen coating in the oxidation rate of poultry fat in dry cat food.

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# CHAPTER 2

# LITERATURE REVIEW

## Lipid Oxidation

Lipid oxidation is a major cause of food spoilage (Nawar, 1985) and a primary cause of reduced shelf life in dry products (Cowell et al., 2000). Lipid oxidation is of great economic concern to the food industry because it leads to the development, of various off-flavors and off-odors, rancidity, which renders these fatty foods unacceptable or reduces their shelf-life. Lipids can be oxidized by enzymatic and nonenzymatic mechanisms (Nawar, 1985). There are many factors that affect the rate of lipid oxidation in a product including the amount of oxygen present, degree of unsaturation of the lipids, presence of antioxidants, presence of prooxidants, especially copper and lipoxygenase, nature of packaging material, light exposure and temperature of storage (deMan, 1999). Oxidative reactions can cause a decrease in the nutritional quality of food, by degradation of vitamins and essential fatty acids, and certain oxidation products are potentially toxic (Nawar, 1985; Cowell et al., 2002).

Lipid oxidation involves the reaction of oxygen with free radicals. The formation of a peroxide occurs by initial removal of a hydrogen atom from a methylene group adjacent to the double bond of the unsaturated fatty acid (deMan, 1999). Further decomposition of hydroperoxides yields a variety of volatile and non-volatile flavor compounds as secondary oxidation products (Table 2) (Ho and Chen, 1994).

**Table 2. Volatile Aroma Compounds**

| | Compound | Aroma |
|---|---|---|
| **Aldehydes** | Hexanal | Green, beany |
| | Heptanal | Green |
| | Nononal | Floral,citrus,orange |
| | Propionaldehyde | Sharp,pungent |
| | 2-Butanone | Ethereal |
| | trans 2-Hexenal | Sweet, floral |
| | trans 2-Heptenal | Pungent, green |
| | trans 2-Octenal | Green,herbaceous |
| | trans 2-Nonenal | Cardboard |
| | Acetaldehyde | Ethereal, pungent |
| | Valeraldehyde | Woody, vanilla, fruity |
| **Alcohols** | Eugenol | Spicy, cloves |
| | 1-Decanol | Floral |
| | Geraniol | Lemon floral |
| | cis-3-Hexenol | Grassy |
| **Alkynes** | 1-Octen-3-ol | Mushroom |
| **Carbonyls** | Octanal | Fatty, citrus |
| | Decanal | Sweet, Waxy |
| | Citronella | Powerful lemon, green |
| **Carboxylic Acid** | Isovaleric acid | Cheesy |
| | Butyric acid | Rancid |
| | Isovalerate | |
| **Esters** | Methyl caproate | Pineapple, ethereal |
| | Citronellyl acetate | Citrus, Rose |
| | Amyl acetate | Banana |
| | Geranyl acetate | Rose, floral |
| | Ethyl hexanoate | Pineapple |
| **Furans** | 5-Methyl furfural | Papery |
| **Ketones** | 2,3-Butanedione | Diacetyl, buttery |
| | Non-2-enal | Cucumbers |
| | p-Menthane-8-thio-3-one | Catty |
| | 1-Octen-3-one | Mushroom/metallic |
| **Sulfides, Disulfides and Mercaptans** | Dimethyl disulphide | Cooked vegetable |
| | n-Propanethiol | Onion |

(deMan, 1999; Anon., 2001;Cadwallader et al., 1994; Ho and Chen, 1994; Friedrich and Acree, 1998)

Volatile compounds like aldehydes (hexanal- “green”, “beany”; heptanal - “green”), ketones (1-octen-3-one - “metallic” or “mushroom”), furans, alcohols, alkanes, alkenes and alkynes (1-octen-3-ol - “mushroom”) are produced from the oxidation process (Cadwallader et al., 1994; Ho and Chen, 1994). The changes in aroma and flavor of oxidized foods are normally attributed to the secondary oxidation products. Secondary oxidation products can be measured by various analytical procedures, including the benzidine value or thiobarbituric acid value (TBA), which is related to aldehyde decomposition products (deMan, 1999). As the aldehydes are oxidized, free fatty acids are formed; these free fatty acids may be considered tertiary oxidation products (deMan, 1999).

Saturated fatty acids have single bonds along the carbon chains, these saturated fatty acids can be divided into groups on the basis of the fatty acid chain length. These groups can be classified as: short (C4-C10), medium (C12-C16) and long (≥C18) chain fatty acids. Unsaturated fatty acids are classified depending on the position and number of double bonds present in the chain. The standard IUPAC (International Union of Pure and Applied Chemistry) terminology indicated the position of the double bond is identified by the number of the carbons, counting from the carboxyl end of the carbon chain. Essential fatty acids can be incorporated into the diet of felines by the incorporation of poultry fat into the pet food. Poultry fat contains high amount of palmitic (C16:0), stearic (C18:0), oleic (C18:1n-9), and linoleic acids (C18:2n-6) (Robey, 2003). Oleic acid (18:1n-9) is produced in animals, is the most common unsaturated fatty acid and is the precursor for other polyunsaturated fatty acids (PUFAs) in plants (Watkins and German, 2002). Linoleic acid (18:2n-6) is not produced by animals and therefore must be

supplemented into the diets. Linoleic acid is a precursor for the production of essential fatty acids such as arachidonic acid (Watkins and German, 2002). α-Linoleic acid (18:3n-3) is a metabolic precursor in the production of n-3 fatty acids in animals. Eicosapentaenoic acid (20:5n-3) has been shown to form by the denaturation or elongation of α-linoleic acid (Watkins and German, 2002). Eicosapentaenoic acid (EPA) can be produced in animals by β-oxidation chain shortening of docosapentaenoic acid (Watkins and German, 2002). Polyunsaturated fatty acids, with two or more unsaturated sites can be oxidized causing the loss of essential fatty acids, formation of free radicals and the development of rancid off-flavors and aromas (Bell, 2001). Poultry meats, especially turkey meat, are highly susceptible to oxidation because of high levels of (PUFAs) (Meynier et al., 1999). Fatty acid profiles of foods can provide an indication of oxidative stability (Rhee et al., 1999).

Some factors that may be responsible for poultry flavors in their skin include sex and age of the bird, stability of lipid components particularly as related to diet and autoxidation and the development of liable sulfur and carbonyl compounds (Thomas et al., 1971). Sulfur compounds play a very important role in poultry flavor. A number of sulfur containing compounds are present in poultry meat, including cysteine, cystine, methionine, taurine and glutathione (Thomas et al., 1971). These sulfur containing compounds are thought to produce the meaty aromas that are associated with poultry flavors. In the heating process, thiamin degradation and lipid oxidation are the two main reactions occurring to produce the flavor of meat (Machiels et al., 2003).

Processors of turkey skins have been less than satisfied in attempts to utilize skin (Thomas et al., 1971). Turkey skins are often used as a source of turkey flavor within a

product. However once cooked, the turkey skin rapidly undergoes autoxidation and the product becomes rancid quickly (Mecchi et al., 1956). Odor regenerated from turkey skin carbonyls can elicit the following responses from an expert taste panel: methyl ketone- oily, minty; alkanal-meaty, turkey-like; alk-2-enal- strong, oxidized, broth-like; alk-2, 4 dienal- strong, painty, nutmeg-like, and spicy (Dimick and MacNeil, 1970).

Oxidation rates can be greatly affected by water activity ($a_w$) of a product. Water can have a protective effect that can cause a reduction in the activity of metal catalysts and can promote nonenzymatic browning. Nonenzymatic browning can result in compounds that possess antioxidant capabilities and impede the access of oxygen to the food (Nawar, 1985). Moderate water activity levels in food, such as $a_w$=0.55-0.85, results in an increased rate of oxidation compared to lower levels (0.3-0.4). The increase in the rate of oxidation is probably a result of increased mobilization of the catalysts present in the food (Nawar, 1985). Very low moisture contents ($a_w$ <0.1), such as observed in dried foods, also can cause very rapid oxidation due to lower stability and faster breakdown of non-hydrated peroxides (Nawar, 1985). Increasing the water content to $a_w$ of about 0.3-0.4 helps retard lipid oxidation and often produces a minimum rate of oxidation (Nawar, 1985). Water activity of dried pet food is approximately 0.4.

Another problem is staling of food stuffs which is often attributed to starch retrogradation. The rate of staling is temperature dependent (deMan, 1999). Texture changes associated with staling can be attributed to the emulsifiers that interact with starch molecules, but the impact on palatability may be indirect (Deffenbaugh, 2000). Staling can cause binding of food volatile aromas into starch inclusion complexes, which can cause an alteration in the overall aroma profile (Deffenbaugh, 2000). During storage,

staling of food stuffs can occur which can have significant changes in the aroma profile such as decrease in “meaty” aroma or increase in “painty” or “varnish” aromas. However, chemical analyses of flavor and aroma compound are too complicated for practical use for product development guidance (Deffenbaugh, 2000). Aromas such as “painty”, “meaty” and “varnish” have been identified in dry pet food. A decrease in the “meaty” aroma has been related to rancidity of fats by free radicals, as well-as the development of “painty” off-aroma (Deffenbaugh, 2000). Such aroma and flavor characteristics have a negative food quality impact to humans, however much less is known about the influence on feline perception of cat food palatability.

**Analysis of Volatile Aroma Compounds**

Analysis of volatile compounds can be indirectly related to the aroma and flavor profile of the food product. The detection and identification of volatiles from the food matrix under various processing and storage conditions can provide clues for the association of detectable flavor and odor changes. Various methodologies, such as headspace methods by direct injection or headspace concentration, trapping methods by cryogenic trapping or adsorbent trapping, distillation and solvent extraction are commonly used to collect and concentrate volatile compounds within a food matrix or the headspace above the sample. Each methodology used for analysis of volatile compounds has a given set of advantages and disadvantages. Techniques that are accurate, efficient, easy and reduce organic solvent waste are desirable. Solid phase microextraction (SPME) is one method that recently has been developed to meet this need. This method involves the extraction of specific organic analytes directly from aqueous samples or from the

headspace of closed sample vials. The use of the SPME fiber combines the sampling and concentration step to reduce time. The volatile compounds are adsorbed to a fused-silica fiber coated with a polymeric liquid phase such as poly(dimethysiloxane) or polyacrylate. The fiber containing the adsorbed compounds are removed and thermally desorbed in the heated injector of the gas chromatography (GC). This technique is very simple, fast and no organic solvents are used. Another advantage of headspace SPME is that sample from any matrix can be analyzed since the fiber is not in direct contact with the sample.

Solid phase microextraction has been used with gas chromatography-olfactometry (GC-O). This system allows the concentration of the volatiles on the SPME fiber seperation on the chromatographic column. Once on the GC column, the compounds can be expelled into a sniffer port to allow the human nose to smell and identify the volatiles being desorbed. The human factor allows for the creation of a profile of odor active compounds. This odor profile that can be used to observe aroma differences as an effect of storage conditions or ingredients commonly used. Aromas that attribute a positive contribution to the overall aroma have been shown to decrease during storage, which may be attributed to staling. Odor profiles have been developed to aid in the identification of off-aromas. Gas chromatography-olfactometry analysis is a technique that combines the resolution power of the gas chromatography with the sensitivity of the human nose.

**Measurement of Oxidation Products**

Gas chromatography and related techniques require expensive equipment and skilled analytical chemists to evaluate the complex data obtained from such analysis. Thiobarbituric acid reactive substances (TBARS) test, a simple analytical method, is

often used to evaluate the extent of lipid oxidation in food systems (Nawar, 1985). A secondary product of lipid oxidation is malonaldehyde, a dienal (two double bonded carbons within a chain), which is formed along with various aldehydes, ketones and epoxides. Malonaldehyde is produced during the termination stage of lipid oxidation. Formation of malonaldehyde is subsequently the basis for the TBARS method (Nawar, 1985). Thiobarbituric acid reactive substances (TBARS) produces a color reaction with oxidation products of unsaturated systems (Nawar, 1985). Thiobarbituric acid reactive substances (TBARS) reactive materials can be produced in large amounts from fatty acids that contain two or more double bonds. Many alkals, alkenals and 2,4-dienals produce a yellow pigment (450 nm) in conjunction with TBA, but only dienals produce a red pigment (530 nm) (Nawar, 1985).

Peroxide values are another method used to measure the amount of lipid oxidation in food products. Peroxides are primary products of autooxidation (Nawar, 1985). The formation of hydroperoxides occurs during the propagation stage of oxidation. Peroxides are normally very unstable and break down to form secondary oxidation products. The secondary oxidation products include a variety of compounds like carbonyls. During the course of oxidation, peroxide values reach a peak and then decline (Nawar, 1985). Initially, the amount of hydroperoxides increases slowly; this stage is termed the induction period (deMan, 1999). By the end of the induction period there is a rapid increase in the peroxide levels. Because peroxide values are easily determined in fats, it is frequently used to measure the progress of oxidation (deMan, 1999). However, peroxides have no importance to flavor deterioration, which is completely caused by the secondary oxidation products (deMan, 1999).

Various attempts have been made to correlate peroxide values with the development of rancid flavors (Nawar, 1985). Good correlations are sometimes obtained, but very often the results are inconsistent (Nawar, 1985). It should be pointed out that the amount of oxygen that must be absorbed, or peroxides that must be formed, to produce rancidity vary with the composition of the oil (the more saturated fats require less oxygen absorption to become rancid), the presence of prooxidants and trace metals, and the conditions of oxidation (Nawar, 1985).

Peroxide values and TBARS have similar advantages and disadvantages. The TBARS method has some limitations in certain food systems. TBARS can react with compounds such as sugars and non-enzymatic browning products that can be present in foods, which has been shown to produce some biased results. With the use of peroxide values there is some concern with experimental error that can occur due to subjectivity in visual endpoint determination. Peroxide values can also be done by colorimetric methods or triiodide in the UV range. However, the disadvantage of these methods is directly related to the higher expense.

**Flavor and Palatability Enhancers**

Fat application to the outside of dry pet food kibble serves as an excellent flavor enhancer and a good source of energy (Trivedi and Benning, 1999). The addition of fat coatings to the kibble has many beneficial advantages for pet nutrition: it contributes flavor, provides essential fatty acids, enhances food palatability, increases energy density of rations and feed efficiency, counteracts heat stress and constipation, improves absorption of fat-soluble vitamins and serves as an efficient energy source (Anon., 2003).

Animals convert fat to heat energy to maintain body temperature and energy for growth, strength and vital bodily functions. Animal fats have the potential to oxidize causing decreased palatability, destruction of nutrients and the formation of toxic compounds. The fats are subjected to many quality tests to ensure that product specifications are met (Anon., 2003).

The fat applied to the kibble should be of high quality and be low in free fatty acids and peroxides. The fat also should not contain odors, like scorched or fecal odors, that might be objectionable. Little or no rancidity should be in the fat coating. A rancid odor also can be objectionable. Cats do not like bitter flavors; this is one mechanism that keeps them from consuming harmful chemicals. A rancid flavor can sometimes incorporates a bitter note.

The addition of fat to feeds also aids in the protection of the machinery and the workers that are involved in the processing of the feeds. Feeds are very abrasive and dusty and can cause excessive wear on equipment (Anon., 2003). The addition of fat reduces the abrasiveness; this in return increases the life of feed mixing and handling equipment. The expense of dust collection by mechanical means is a major item of cost in manufacturing feed. The addition of fat to feeds help to minimize all problems associated with feed production.

**Fat-soluble vitamins**

Fat soluble vitamins A, D, E and K are important nutrients in pet foods. Pet foods are produced to provide balanced nutrition because animals have no means of supplementing their diets. The feline requirements for these vitamins are 36,000 I.U. for

vitamin A, 50 I.U. for vitamin E and 2000 I.U. for D on the basis of quantity per kg of feed stuff, assuming that 90% is dry matter (Morton, 1970). In addition to having vitamin functions, some forms of vitamin E (as alpha-tocopherol), is an antioxidant and, if applied directly to feeds, is consumed rapidly by free radicals to help reduce or retard oxidation (Coelho, 2000).

Many vitamins are sensitive to the presence of oxygen and oxidizing substances and can undergo oxidative reactions resulting in degradation and loss of vitamin activity (Bell, 2001). Vitamin oxidation can be due to propagation of autooxidation of fats, Fenton-type included-oxidation by trace minerals, hydrolytic-induced oxidation and microbial induced oxidation (Coelho, 2001). There are several factors that influence vitamin stability in premixes, pelleting and storage: these are temperature, humidity, conditioning time, reduction and oxidation (redox) reactions and light (Coelho, 2001). Therefore, changes can occur in vitamin oxidation throughout the process of pet food manufacturing. For this reason many companies check their vitamin levels at many stages of production, including straights, premixes, extrusion and pet food storage, because vitamin losses vary from process to process (Coelho, 2001). Processing can cause the fat itself to oxidize which then will cause the fat-soluble vitamins to oxidize by autooxidation (Coelho, 2000).

**Edible Films**

Strategies for protecting fat components of dry pet foods from oxidation include providing a barrier between the fat and the oxygen source (air). Edible coatings or film, that can provide complete coverage of the kibble, may function in that role. Edible films

and coatings are edible materials applied on or within foods in thin layers by wrapping or immersing, brushing or spraying in order to produce a selective barrier to protect against the transmission of gases, vapors and solutes while also offering mechanical protection against breakage (Robertson, 1993). Edible films in the food industry have great potential in prolonging shelf life of certain foods.

Early applications of edible films included prevention of dehydration of citrus fruits, prevention of meat shrinkage with fat coatings and edible protective coating (sucrose) on nuts, almonds and hazelnuts to prevent oxidation and rancidity during the storage process (Debeaufort et al., 1998). Advances in the formulation, applications and characterization of edible films and coatings have occurred over the past 40 years, as evidenced in both scientific and patent literature (Debeaufort et al., 1998). For example, the application of edible films and coating to fruits has permitted the extension of shelf-life and quality providing extended distribution and sale of seasonal fruits. The coating may be applied as an emulsion of waxes and oil in water spread on fruits and functions to improve their appearance, such as their shininess and color, retard softening and onset of mealiness, serve as a carrier of fungicides and provide control of ripening, and to reduce water loss (Debeaufort et al., 1998). Edible films and coatings, which function both as food components and packaging layers, must fullfill some requirements. These include:

1.Good sensory qualities
2.High barrier and mechanical efficiencies
3.Enough biochemical, physico-chemical and microbial stability
4.Free of toxins and safe for health
5.Simple technology
6.Nonpolluting
7.Low cost of raw materials and process (Debeaufort et al., 1998).

Edible films may have many different functional properties including acting as a water barrier, controlling gas (especially oxygen) exchanges, and carrying encapsulated food additives or ingredients such as antimicrobials and antioxidant agents. Edible coatings are typically applied by spray fluidization, falling and pan coatings, spraying, dipping, or brushing on a food product (Debeaufort et al., 1998). Aqueous products are dried and lipid-based coating are cooled before the film is applied. The adhesive quality of the film is dependent upon the food product's surface. Emulsifiers may be used to improve the sticking of a hydrophobic coating on very hydrophilic food products (Debeaufort et al., 1998). The film's thickness is based on the application technique used and the viscosity of the coating solution. The thicker the solution the fewer application techniques available.

Many proteins have the mechanical and physical properties necessary for forming edible films. Edible films have been made form corn zein, wheat gluten, soy protein, egg white, wool keratin, cottonseed, whey, casein, fish myofibrillar protein and collagen. Some of these proteins are used more than others because of allergy issues and cost factors associated with edible films. Many different protein films exist in the food industry as a way to give longer shelf-life to foods. This review will focus on collagen as a source material for edible films.

**Collagen as an Edible Film**

Collagen is an abundant protein constituent of connective tissue in vertebrates and invertebrates (Gennadios, 2002). The collagen in meat is very similar to the collagen found is skin, ligaments and tendons. Collagen is composed of a primary structure of 18

amino acids. Collagen is rich in glycine, hydroxyproline and proline and exists in the form of a triple helix structure. The triple helix is right-handed and contains about 1000 residues (300 nm) in length in fibrous collagens with three amino acids per turn (Bailey and Light, 1989). It is a hydrophilic protein because of the greater content of acidic, basic and hydroxylated amino acid residues than lipophilic residues. The stability of collagen is a function of the hydroxyproline residues and bound water; this can cause variation in the melting temperature of the helix (Bailey and Light, 1989). The helix is tightly packed to help aid in the resistance to proteolytic attack.

Based upon the macromolecular structure, collagen can be divided into three major groups: (a) striated fibrous collagen which includes type I, II and III collagen, (b) nonfibrous collagen which contains type IV as 'basement membrane collagen', and (c) microfibrillar collagen, which emcomposses type VI and VII (the matrix micrifibrils), type V, IX and X (the pericellular collagen), and types VIII and XI which are yet classified (Hood, 1987). Type III collagen is located in embryonic tissue, scar tissue, skin, arteries, heart valves and many intra-organ connective tissue (Bailey and Light, 1989). Type III collagen has been removed from skins and other sources to form collagen films.

In the identification of collagen using a Sirus red stain can show the collagen intensity. The Sirus red stain shows the denatured fibers as red; however, a color range of green to yellow or gold can be observed depending on the diameter of the fiber (Bailey and Light, 1989). In connective tissues like skin and intramuscular connective tissue, the fiber orientation is more random and content of collagen is lower. This causes the

ultimate tensile strengths recorded in mechanical tests to be considerably lower (Bailey and Light, 1989).

The total amount of collagen that can be produced in meat increases with the age of the animal and is directly related to animal size. As the animal grows, the collagen fibers increase in number and the bundles become larger and more complex (Bailey and Light, 1989). Older animals do not necessarily have greater amounts of collagen, but they do have tougher collagen (Meat Ingredients, 2003). Furthermore, as collagen ages it can become progressively stronger and more rigid. This might be caused by an increase in number of cross-links of reducible aldimines or oxo-imine (Bailey and Light, 1989). Cross linking in collagen can be grouped into two categories intramolecular cross-links and intermolecular cross-links. Mature cross-links have been shown to be stable to high temperatures and extreme pHs (Bandman, 1987). The number of reducible cross-links decreases with aging, which could be the precursors for more complex nonreducible collagen (Bandman, 1987).

The properties of collagen and gelatin are of great interest to various fields such as surgery (implantations; wound dressings), leather chemistry (tanning), pharmacy (capsule production; tablet binding), and food science (gels; edible films) (Gennadios, 2002). Nature has caused the formation of a multitude of hydrophilic membranes that are collagen based (Maser et al., 1991). Very few reports have been made on the use of collagen films in membrane separation processes (Maser et al., 1991). This is despite the fact that collagen sources are easily accessible and almost inexhaustible. Collagen membranes have been shown to have high flux at relatively low temperatures during pervaporation processes (Maser et al., 1991). This application of collagen membranes

gives the possibility of economically concentrating aqueous solutions of compounds, that are heat sensitive, such as, fruit juice aromas and fragrances (Maser et al., 1991). The other benefit of collagen membranes is that they are greatly compatible with food systems.

**Extraction of Collagen**

The process of extracting collagen requires the addition of chemicals such as salts, phosphates and acids. All of these chemicals can cause a change in the water holding capacity, pH, and water uptake, of the collagen. The water holding capacity of collagen has not been shown to be greatly affected by NaCl (Bailey and Light, 1989) but a decrease in water holding capacity has been observed at a pH below 5 or above 8. If the pH is 6 to 8 with optimum conditions, there is a slight increase in the water content of the collagen (Bailey and Light, 1989). Furthermore, if the concentration of NaCl is high, a decrease in the hydration of collagen can occur and the normal swelling of collagen in acids can be inhibited by the addition of salts (Bailey and Light, 1989). Collagen is minimally hydrated at a pH range 6-8, and hydration will increase significantly at extreme values on the pH scale (Bailey and Light, 1989). Therefore, the collagen matrix is able to uptake water at low pHs (below pH 5) and to some degree at higher pHs (above pH 8). The presence of increased mature cross-linking in the matrix has been attributed to the decrease in the water uptake (swelling) of insoluble collagen from older animals and can be used as a measure of this parameter (Bailey and Light, 1989).

When collagen is heated it forms gelatin. Gelatin is denatured collagen, which is formed due to the heating process. Gelatin can also be described as denatured and partly

degraded product from animal collagen, obtained from skin or bones (Bailey and Light, 1989). The gels that are produced by gelatin are generally clear and strond enough for use in foods and forms good cold-setting gels under many different conditions with a wide range of pH. About 65% of gelatin manufactured worldwide is used in food applications. With the collagen extracted it can now be suspended into a solution and used as an edible film or coating.

**Collagen Films**

Problems have arisen for poultry processors by the production of a considerable amount of skins produced as by-products from convenience products. The increase in convenience products produced without skins has caused an increase in the amount of low-value skin by-products. The utilization of poultry skins for production of collagen films, instead of conversion into animal feeds, could be of economic value to the rendering plants. MacNeil and Buss (1968) reported that skin yields varied from 6-12% by weight of eviscerated carcass in different strains of turkey. However, extraction of collagen from chicken skins lead to an extraction yield of 38.9% collagen consisting of types I and III collagen (Cliché et al., 2003). Therefore, chicken skins appears to be a good source of collagen.

A collagen film is a protein-based edible coating which is produced by the extraction of collagen and suspension into a liquid state. Collagen films can be used as a protective barriers. Collagen films have good oxygen barrier properties on food at which the storage conditions are at low relative humidity environments (Gennadios et al., 1997). Although collagen films are sensitive to relative humidities, they can be applied to reduce damage to foods during handling and transportation (Chen, 1995). Collagen films do

have some limitation that range from extreme pH ranges, high temperatures and microbiological damage (Maser et al., 1991). Cross-linking can reduce some of these limitations and plasticizers may be added to improve barrier properties.

Collagen and gelatin coatings have been used throughout the years to reduce gas permeability and water vapor permeability for meats and sausages. The application of a collagen film reduces shrink loss, increases juiciness, and allows for easy removal of nets after cooking for a variety of meat products including hams and sausages (Gennadios et al., 1997). Collagen films have been used primarily as casings and wraps for ground meat products, particularly sausage (Hood, 1987). Commercially available collagen films from bovine and porcine sources have been shown to inhibit moisture loss and oxygen transport while providing structural integrity for meat products (Gennadios, 2002).

The use of collagen coatings also can help to increase the mechanical properties of foods by increasing the physical properties of the film. Tensile strength and elongation are equally important physical properties for edible film applications (Gennadios, 2002). When collagen films were subjected to stress, tropocollagen molecule within the film did not entangle, allowing the recovery of the original shape of the film. Collagen fibers were strong under tension having a tensile modulus of 100 to 1,000 Mpa (Gennadios, 2002). Collagen films with a high tensile strength can help protect the food product during handling and transportation. Films and coatings can aid in protection after the primary package is opened or removed. Antioxidants also can be incorporated into an edible protein film to help control oxidation of the product.

**Antioxidants**

Antioxidants are used in food products to help stabilize them increase shelf life, and delay the onset of oxidation (Nawar, 1985). Antioxidants have been used for many years to help decrease the onset of autooxidation by reacting with free radicals, thus terminating the chain reaction (deMan, 1999). Autooxidation of polyunsauturated lipids consists of a radical chain type mechanism (Loliger, 1989). The antioxidant (AH) may react with the fatty acid radical or with the peroxy free radical (deMan, 1999). Antioxidants attempt to trap free radicals that promote oxidation. Lipid-soluble antioxidants, butylated hydroxyanisole (BHA), butylated hydroxytolulene (BHT) and tocopherols, which combine with free radicals, are normally not affected by water content or water activity (Labuza, 1971). The free phenolic hydroxy group in these molecules are responsible for their antioxidant activity (Coelho, 2000).

Antioxidants for food applications should be cost effective, improve product quality and value with relative low cost. Antioxidants should be effective at low concentrations, have no sensory influence such as off-taste, off-color or off-aroma, and should not be toxic. The most commonly used antioxidants in the U.S. are butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT), *Tert*-butyl hydroquinone (TBHQ) and α-tocopherol. The synthetic antioxidants are mainly phenolic compounds; the natural antioxidants include the tocopherols and ascorbic acid. Antioxidants have been found to be most effective at levels of .01% or less (Frankel, 1998). Antioxidant properties can vary based on the substrate or the matrix in which the antioxidant is being added.

Antioxidants should be evaluated to determine its effectiveness. The effectiveness of an antioxidant is a very complex phenomena which is determined by the physical state of the lipid substrate, conditions of oxidation, methods used to observe the oxidation and finally, the stage of oxidation (Frankel, 1998). Functionality of natural antioxidants can be affected by emulsions and multi-component foods that cause a complex interfacial phenomena to occur. Antioxidant evaluations should be carried out using various methods to measure oxidation and should be tested under various conditions. Antioxidants should be compared at the same concentration of active components.

The conversion from synthetic to natural antioxidants has occurred because of an increased interest in using natural additives to keep labels "all natural". Some concerns with toxicity have also lead to the conversion from synthetic to natural antioxidants. This is leading the industry to look at natural plant phenolic compounds like spice extracts such as rosemary, amino acids and even proteins.

Phenolic antioxidants are used to terminate free radical chains in lipid oxidation (Hudson, 1990). Synthetic antioxidants, BHA and BHT, are primary antioxidants which react rapidly with a free radical and produce a stable radical. The phenol group in both BHA and BHT is vulnerable to having a hydrogen atom removed leaving a radical. The radical formed is relatively stable since it is delocalized around the benzene ring.

BHT has been used in the stabilizing of animal fats such as lard and is more effective than BHA (Madhavi et al., 1996). BHT is normally used in low-fat foods, fish products, packaging materials and mineral oils. BHT has been found to be better at stabilizing than a combination of BHA/BHT (Madhavi et al., 1996).

For fresh raw meats, BHA has the capability of inhibiting lipid oxidation at a level of .01% (Frankel, 1998). BHA antioxidant activity can continue to increase with concentration up to .02% (Frankel 1998). BHA has been widely used in chewing gums to aid in retarding flavor loss, off-flavor development, toughness and brittleness due to oxidation. One of the most important properties of BHA is its ability to remain active at elevated temperatures. BHA has been shown to be effective in stabilizing shelled nuts in conjunction with an edible protective coating. BHA has been used in fats, oils, fat-containing foods, confectioneries, essential oils and food-containing materials. BHA is more fat soluble than BHT.

BHA and BHT have been found to be subject to significant loss at elevated temperature, due to BHT being somewhat volatile. In a study conducted by McCarthy and others (2001), raw pork patties with synthetic antioxidants (BHA and BHT) had a lower TBARS value for days 3,6, and 9 than the raw pork patties with natural vitamin E. A combination of BHA with BHT has been effective in stabilizing shelled walnuts, ground pecans and peanuts (Madhavi et al., 1996). BHT is commonly used with BHA and citric acid for the stabilizing high fat foods and oils (Madhavi et al., 1996). The use of citric acid has shown to help increase the effectiveness of BHA. A combination of antioxidants with the use of citric acid has shown increase the antioxidant properties. Synthetic antioxidants have been shown to be more effective than natural occurring antioxidants.

Tocopherols are the most widely distributed antioxidants in nature and constitute the principal antioxidant in vegetable oils. Tocopherols in natural fats are usually present at optimum levels. Addition of antioxidant beyond optimum amounts may result in

increasing the extent of prooxidant action (deMan, 1999). α-Tocopherols tend to exhibit prooxidant activity if the level is above 100mg/kg. α-Tocopherol has been identified as the most potent of the natural tocopherols. Tocopherols with high in vivo vitamin E activity are less effective as in vitro antioxidants than those with low vitamin E activity. The order of antioxidant in vitro activity is this δ>γ>ß>α for tocopherols.

α-Tocopherol is most effective in animal fats at a concentration of .01% and low temperatures of 20° C. For higher temperature conditions of 97°C, γ-tocopherol is most active. Tocopherols are effective in enhancing color stability and retarding lipid oxidation and off-flavor development in beef, pork, turkey and chicken meat when the animals are feed diets that are rich in tocopherols prior to slaughter (Madhavi et al., 1996). α-Tocopherol at high concentrations showed an increase in the hydroperoxide formation, however at increasing concentrations hexanal formation was inhibited. The ability of antioxidants to inhibit hexanal formation may be more relevant to flavor development.

Vitamin E has a potential to be an antioxidant or a prooxidant, depending on its concentration, the lipid composition, and the overall food matrix. There has been no reported level of vitamin E used in coating systems, where it serves as an antioxidant or a prooxidant (Lee and Krotcha, 2002). Another study conducted by Mate and Krochta (1997) showed that antioxidants present in the coating contributed to an increase of the stability of coated walnuts. This was noticed by a longer induction period, which causes a longer onset of rancidity process (Mate and Krochta, 1997). The use of tocopherols as antioxidants in whey protein isolate coatings resulted in a longer shelf life of walnuts. Tocopherols have been shown to be most effective when used in conjuction with other antioxidants or synergists than when used by alone.

Chelates are commonly referred to as synergists, acting to enhance phenolic antioxidants such as BHA and BHT. Chelating agents have been shown to cause a reduction in the prooxidant effect of trace minerals in foods. Citric acid, a chelating agent, is commonly used to help extend the shelf-life of lipid-containing foods by binding metallic ions such as copper and iron that can promote lipid oxidation through a catalytic reaction (Hudson, 1990; deMan, 1999).

Phospholipids are synergists that have been shown to be useful in reinforcing the antioxidant activity of phenolic compounds. As an emulsifier the antioxidant effect of phosopholipids has been explained by their ability to improve the affinity of the tocopherols and phenolic antioxidants toward the lipid substrate (Frankel, 1998). Different lipid substrates can cause a direct impact on the activity of antioxidants by being either hydrophilic or lipophilic. Phosopholipids have a tendency to produce browning materials when heated at elevated temperature. The browning materials can act as reducing agents that are effective antioxidants in food systems (Frankel, 1998).

**Conclusions**

For many years now the use of collagen has been primarily been for sausage casings and now collagen films are used on hams and other meats to prevent shrink loss and serve as protective barriers. Collagen films have not been used with the incorporation of antioxidants into the films. This might be an interesting area for further research. It seems that the food matrix plays a very vital role on how the antioxidant will react; this could result in an antioxidant effect or a prooxidant effect.

Edible films and coating are being investigated as value-added products, to increase shelf-life and aid in reducing packaging costs. Edible films will be a new age packaging to aid in the reduction of packaging waste that is occurring in the world. The application of collagen films to dry pet foods can have many potential purposes such as aiding in prevention of oxidation, increase mechanical integrity and increased shelf-life. The feed company examines such aspects as way to improve the product and deliver a better product to the consumers.

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# Use of Poultry Collagen Coating and Antioxidants as Flavor Protection for Dry Cat Food Made with Rendered Poultry Fat

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Keyword: oxidation, pet food, TBARS, antioxidants, collagen

# CHAPTER 3

## ABSTRACT

Poultry skins and rendered poultry fat are by-products produced in excess at rendering plants. The use of low value by-products such as poultry collagen, from poultry skins, and fat to improve flavor and quality in dry pet food could be economically attractive. This study examined a poultry collagen coating as a protective barrier against oxidation in dry cat food made with rendered poultry fat. Collagen was extracted from chicken skins, dissolved in an acidic solution, applied to dry cat food and dried to form a surface film. Six treatments were examined: kibble, kibble with fat, kibble with collagen, kibble with fat and collagen, kibble with fat, BHA/BHT and collagen and kibble with fat, tocopherol and collagen. There were two storage conditions: 'jungle condition' (42°C and 83% relative humidity) and 'ambient condition' (21°C and 51% relative humidity). In 'jungle conditions', thiobarbituric acid reactive substances (TBARS) was measured over an eight-day period at day 0, 2, 4, 6, and 8. In 'ambient conditions', TBARS was measured over a thirty-day period at day 0, 7, 14, 21, and 30. Water activity and moisture contents were measured. There were significantly higher TBARS ($P<0.05$) for the control kibble at both storage conditions. There was significantly higher fat percentage ($P<0.05$) in all treatments with the additional fat coatings. Fatty acid compositions showed slight changes during storage. There were some changes in the aroma profile of the kibble with fat treatment having musty, moldy and plastic aromas at both storage conditions. The volatile aromas might be an indication of oxidation in the poultry fat.

**Key words:** cat food, oxidation, poultry by-products, TBARS

# CHAPTER 3

## INTRODUCTION

Over 46 billion pounds of perishable materials generated annually by livestock, poultry and food processing are recycled by the rendering industry. In 1996, the production value of rendered products in the U.S. was approximately $3.0 billion (Anon., 2003). Animal protein meals also are excellent sources of calcium, phosphorus, protein and essential amino acids. Poultry fat and poultry skins, source of poultry collagen, are rendered products of the poultry industry.

Rendered products are utilized extensively in the formulation of pet foods. The pet food industry is very competitive. In 2001, 55% of all American households were home to at least one pet cat or dog, with a total estimate of 110 million cats and dogs requiring feed (Dominy, 2002). Poultry by-products meals, typically 65-70% protein (Cowell et al. 2000), are widely used in dry cat food as a source of protein and fat (BeMiller 1996). Dry pet foods historically have been available commercially and make up approximately 48% of all pet foods produced and marketed.

In dry pet food, the main source of fat is either beef tallow or other types of animal (poultry or pork) fat and, sometimes, vegetable oils. The type of fat added to the dry food depends on different factors. While flavor and nutritional contributions are important, price and oxidative stability are perhaps the most important factors (BeMiller, 1996). Fat is the most expensive ingredient, when fat quality is considered (BeMiller, 1996). Poultry fat is highly susceptible to oxidation causing a limitation in which products the fat can be added since it can affect the aroma and flavor.

Most pet foods have unique sensory profiles for flavor, aroma and textural attributes that contribute to the palatability of the product. Dry pet foods usually require performance, including palatability, be maintained for at least a year after production and packaging to allow for distribution, storage and sales (Kvamme, 2000). During storage, attributes of pet food can either decrease, increase or perhaps even stay the same. Autoxidation of lipids during shelf life of pet foods increases negative attributes and decreases positive attributes (Kvamme, 2000).

Polyunsaturated fatty acids, with two or more unsaturated sites, can be oxidized, causing the loss of essential fatty acids, formation of free radicals and the development of rancid off-flavors and aromas (Bell, 2001). Poultry meats, especially turkey meat, are highly susceptible to oxidation because of high levels of polyunsaturated fatty acids (PUFA) (Meynier et al., 1999). The fatty acid profile can provide an indication of oxidative stability (Rhee et al., 1999).

Mechanisms for protecting fat components of dry pet foods from oxidation are to provide a barrier between the fat coating and the oxygen source (air). Edible coatings or films, that can provide complete coverage of the kibble may function in that role. Edible films and coatings are edible materials applied on or within foods in thin layers by wrapping or immersing, brushing or spraying in order to produce a selective barrier to protect against the transmission of gases, vapors and solutes while also offering mechanical protection against breakage (Robertson, 1993). Edible films in the food industry are showing great potential in the prolonged shelf life of foods.

Problems have arisen for processors by the production of a considerable amount of skins produced as by-products from convenience products. The increase in

convenience products produced without skins as caused an increase in the amount of low-value skin by-products. The utilization of poultry skins into collagen films, instead of conversion into animal feeds, can be of increased economic value to rendering plants. A collagen film is a protein based edible coating, which is produced by the extraction of collagen and suspension into a liquid state. Collagen films can be used as a protective barrier. Collagen films have good oxygen barrier properties on food at which the storage conditions are at low relative humidity environments (Gennadios et al., 1997).

The main objective in this research was to investigate oxidation of dry cat food kibbles, using rendered poultry fat as a flavor and fat source, in addition to antioxidants in the fat to aid in preventing oxidation of the fat, followed by collagen coating which was to serve as a preventative barrier against oxidation. Aroma and volatile compounds were also of interest to see if the odor compounds affected the overall aroma profile, which would also give aromas of oxidation products. These volatile aromas can affect the overall palatability of the dry cat food.

## MATERIALS AND METHODS

### Sample Preparation and Storage

Cat food (dry kibble form) was obtained from an industry provider (Nestle Purina, St. Louis, MO) and rendered poultry fat was provided by Sanderson Farms (Laurel, MS). The cat food samples were vacuum packaged in cryovac bags (Freshpak Nylon/PE vacuum pouch (12"x 16", 3 mil standard barrier)) and the rendered poultry fat was frozen (-12°C) until use. The collagen used for coating was obtained from an extraction of chicken skins conducted at the VPISU food chemistry lab. For all treatments, 1000 grams of cat food were coated according to Table 3. Antioxidants (BHA/BHT and tocopherol) and chelator (citric acid) were added to the rendered poultry fat on a weight to weight basis of 100 ppm of each antioxidant and a chelator. After coating, the treatments were allowed to dry on a metal screen with fans circulating air around the kibbles. After all treatments were dry, the kibbles were placed into standard brown paper lunch bags (13 x 7.9 x 27 cm) and stored under the appropriate conditions.

**Table 3. Sample Preparation of Cat Food by Treatment**

| Treatment | Kibble | Fat | Collagen Coating | Antioxidant/Type | Citric Acid |
|---|---|---|---|---|---|
| Treatment 1 | Yes | No | No | No | No |
| Treatment 2 | Yes | Yes | No | No | No |
| Treatment 3 | Yes | No | Yes | No | No |
| Treatment 4 | Yes | Yes | Yes | No | No |
| Treatment 5 | Yes | Yes | Yes | Yes/(BHA/BHT) | Yes |
| Treatment 6 | Yes | Yes | Yes | Yes/Tocopherol | Yes |

Two storage conditions were used in this study: an ambient storage and an accelerated storage known as 'jungle conditions'. The ambient storage condition was obtained by placing a saturated magnesium nitrate solution into a glass desiccator and

storing at a temperature of 21°C; this gave a relative humidity measurement of 51% (Rahman, 1995). The accelerated storage (jungle) condition, was obtained by placing a saturated salt solution of potassium chloride into a glass desiccator and storing at a temperature of 45°C; this gave a relative humidity of 83-85% (Rahman, 1995). Relative humidity was measured using Traceable® Digital Humidity (Fisher Scientific, Friendswoods, TX). All treatments were placed into both storage conditions. For ambient storage, the treatments were stored for a period of 4 weeks. In the 'jungle conditions' storage, all treatments were stored for a period of 8 days. One week of the accelerated jungle conditions is equivalent to one month of ambient storage.

**Collagen Extraction**

Extraction method was performed according to Ho and others (1997). Chicken skins from a local processor were thawed and excess fat was removed by scraping the skin. The skins were cut into small pieces and defatted using acetone for 10 minutes. The skins then were removed from the acetone and rinsed three times with deionized water. Next, the skins were soaked in 10% NaCl solution at 4°C for 24 hours. Following the 24 hour period, the skins again were washed three times with deionized water and then placed into a citrate buffer solution with a pH of 4.3 for 48 hours. The skins were washed three times with deionized water and placed into the grinder (Kitchen Aid, St. Joseph, MI) for homogenization. After grinding the skins, 500 mL of .1N hydrogen chloride solution (with a pH of 2.5) per 10 grams of dried tissue was added. The skins then were digested by the addition of porcine pepsin in a ratio of 1:50 and stored at 20°C for 24 hours. The solution was placed on a Innova 2000 (New Brunswick Scientific, Edison, NJ), platform

shaker which allowed the solution to be shaken at 100 rpm for 24 hours. Solution (175mL) was placed into 200 mL polypropylene centrifuge tubes and centrifuged for 30 minutes (Sorvall RC-5B Superspeed centrifuge with a GSA rotor model SLA 1500 at 12,500 rpm and 25,429 g force); to remove the insoluble substances in the solution. After centrifugation, the supernatant was collected and the pH was adjusted to 10 using NaOH, then placed at 4°C for 24 hours. Next the solution was adjusted to a pH 7 using a HCl solution. The solution was washed with 500 mL of deionized water in a large 2000 mL beaker. The solution was centrifuged again and the precipitate was collected and washed three times with deionized water. The precipitate was dissolved into a 0.5 M acetic acid solution in the ratio of 0.121 grams collagen per 1 mL acetic acid solution.

**Proximate Analysis**

Protein

The amount of protein in the cat food was analyzed according to AOAC Official Method 981.10 Crude Protein in Meat Block Digestion Method (AOAC 1990). Samples were measured in duplicate using two gram samples per analysis.

Fat

Percent fat was measured using the Soxtec System HT2 1045 extraction unit (Hoeganaes, Sweden). Extraction was done using petroleum ether. Modified AOAC official method 960.39 Fat (Crude) or Ether Extract in Meat (AOAC 1990). Four grams of samples were ground using a mortal and pestle and placed on filter paper; the filter paper was then inserted into the thimble. This method was modified since sand was not incorporated into the thimble for the analysis.

Ash

The ash of the cat food was measured at the beginning of storage in duplicate according to AOAC Official Method 920.153 Ash of Meat using a Lindberg Ashing Oven to a temperature of 600°C for 24 hours (AOAC 1990).

Moisture

The moisture of the beginning and stored cat food was determined in duplicate using the AOAC Official Method 950.46 Moisture in Meat using a drying oven (Blue M) (AOAC 1990). Samples were measured in duplicate; sample weights were three grams.

Water Activity

The water activities of the cat food were measured at the beginning and end points using an Aqua-Lab CX-2 the samples were measured in duplicates. For each analysis one kibble whole was used; placed on a plastic cup and inserted into the machine for analysis. For ground kibble one kibble ground with a mortal and pestle was placed in a plastic cup and inserted into the machine for analysis. The Aqua-Lab CX-2 was calibrated using a saturated NaCl solution obtaining an $a_w$ of .754 (Rahman, 1995).

TBARS

Thiobarbituric acid reactive substances (TBARS) was used to measure the oxidation in cat food. The cat food TBARS method sample weight was approximately 3 grams. The method described by Spanier and Traylor (1991) was used. The direct chemical/extraction method allows for a quicker analysis than the original distillation method. This method maximizes the formation of a color product between thiobarbituric acid and malonaldehyde rather than between TBA and other lipid peroxides by Spanier and Traylor (1991). Cuvettes were read in a Spectronic 21 D (Milton Roy) to determine

the absorbance of the sample. A standard curve was run for absorbance at 0, 2.5, 5, 7.5 and 10; read at 532 nm.

Fatty Acid Analysis

Fat samples were extracted using the Soxtec System HT 2 1045 extraction unit (Hoeganaes, Sweden). Fats were placed into 10 mL test tubes. Samples were then analyzed using the method reported by Maxwell and Marmer (1983). Fatty acid methyl ester samples were transferred into an autosampler vial (Supelco).

Analysis was done on GC Hewlett Packard 5890 (Hewlett-Packard, Palo Alto, CA, USA) with a DB-225 column (30m x.25 mm x .25μm) with a flame ionization detector (FID). The column temperature was set at 140°C and was raised at 4°C/min until reaching 220°C for the final temperature. The final temperature was held for 13 minutes. The sample injection amount was 1μL, the flow through the column was 1.2 mL/min (32 cm/sec). Helium was used as the carrier gas. The injector temperature was 260°C and the detector temperature was 260°C. The slit ratio for the column was 1:100. Integration was done using a HP 3393A (Hewlett-Packard, Palo Alto, CA, USA) integrator.

A standard (Supelco 37 component FAME mix) was run to determine the retention times for identification purposes of the fatty acid methyl esters.

Fatty acids percentages were calculated using the following formula:

=peak area of fatty acid/total peak area of fatty acids *100.

**HPLC Analysis of Vitamins**

The vitamin E standard used was α-tocopherol (Sigma) and the vitamin A standard was all-*trans* retinol (Sigma HPLC). All-*trans* retinol and α-tocopherol were measured using an Agilent 1100 series High Performance Liquid Chromatograph with Chem Station software. The column used was a Zorbax Eclipse XDB-C18 reversed phase column (4.6mm x 150 mm, 5μm). Column temperature was 50°C, the sample injection amount was 1 μL, the flow through the column was 1 mL/min., the diode array signals were 295nm for α-tocopherol, 325nm for all-*trans* retinol. The solvent used was a mixture of 95% MeOH and 5% water.

The peak areas were measured using the auto-integration on the Agilent HPLC. The unsaponifiable matter was prepared from cat food samples as described below.

Vitamin Preparation

Fat was extracted from the cat food by using a Soxtec System HT 2 1045 extraction unit (Hoeganaes, Sweden). This method described by O'Keefe (1984) was used and slightly modified. The fat was the saponified using 1 gram of fat then added 15 mL of ethanol followed by 1 mL of 50% KOH weight to volume solution in to a 50 mL test tube with Teflon-lined polypropylene lids. The samples were then heated in a boiling water bath for 15 minutes; six tubes were run at once and the tubes were shaken every 2 minutes. The tubes were cooled by running cool tap water over them. The solution inside the tubes was then transferred into 500 mL separator funnels that were covered with tin foil. Each tube was washed with 30 mL of distilled water and 30 mL of diethyl ether. The unsaponifiable matter was extracted with diethyl ether (1x100 mL, 2x50 mL). Under these conditions emulsions did not occur, phase separations typically took only 5-10

minutes. The combined diethyl ether phases were washed with distilled water (3x50 mL) and then were transferred to an erlenmeyer flask 500 mL that contained approximately 40 grams of anhydrous sodium sulfate. The flask were stoppered for 10-15 minutes to remove water. The dried diethyl ether extract was filtered (Whatman No. 1 filter paper) with water aspirator suction and transferred to a 500 mL round bottom flask that was covered with aluminum foil. The sodium sulfate residue and flask were rinsed with approximately 50 mL of diethyl ether and added to the round bottom flask. The solvent (diethyl ether) was evaporated using a rotorary evaporator with slight heat (40°C). Then 1 mL of methanol (HPLC grade) was added to the round bottom flask, the solution was then filtered using a .45μm Acrodisc with Tuffryn® membrane filter (Gelman Sciences) into a 2 mL screw top HPLC autosampler clear vial also covered with aluminum foil. The solution was then ready for analysis of all-*trans* retinol and α-tocopherol by HPLC. The chromatography conditions are as described above for these two vitamins.

**Gas Chromatography-Olfactometry Preparation**

A experienced 6 person (6 females) sensory panel consisting of students and staff were used to evaluate the cat food. The panelist was trained in four 20-minute sessions before the study began. Two-aroma training kits, Beer Aroma Recognition kit and Beer Taint Recognition kit (Brewing Research International, UK), were obtained. The Beer Aroma Recognition kit consisted of these aromas: sweetcorn, malty, late hop aroma, rose floral, lemon floral, citrus, spicy, grassy, banana, pineapple, phenolic and butterscotch. The Beer Taint Recognition kit consisted of these aromas: sweetcorn (DMS), phenolic, medicinal, musty, diacetyl, rancid, cheesy, cardboard, catty, papery, cooked vegetable,

onion. Each panelist was given these identified aroma compounds and was instructed to smell the aromas to develop a verbal recognition for the aroma. The aromas for each compound would then be confirmed by a identification sheet.

For the cat food analysis, 3 panelist, selcected for availability and ability, evaluated aromas from the GC-O sniff port, on an intensity scale of 1 to 5 as an estimation of the intensity, with 1 meaning "slight" and 5 meaning "very potent" aroma. All samples were allowed to equilibrate to room temperature before analysis. Three kibbles of cat food were placed in clear crimp top 10 mL vials (Microliter Analytical) with 20 mm Alumi Tin with natural Teflon/Blue silicone septum. List of descriptors were given for identification of volatile compounds (appendix A).

**Solid Phase Microextraction**

The fiber used was a 50/30 μm StableFlex Divinylbenzene/Carboxen/PDMS fiber (Supelco, Bellefonte, PA. 16823-9900); the fiber was exposed to the headspace of the treatment and standard solution for 20 minutes. Prior to use, the fiber was conditioned at 270°C for one hour in the injection port. The desorption of volatiles was conducted in a GC injector with a SPME inlet liner (.75 mm i.d., Supelco Bellefonte, PA. 16823-9900) for 15 minutes with a 35 mm total needle length.

**GC-O Conditions**

GC-O was conducted on a HP 5890A (Hewlett-Packard, Palo Alto, CA, USA) equipped with a flame ionization detector (FID) and a sniffing port (ODO II) (SGE International, Ringwood, Australia) using a DB-5 ms column (30 m length x .25 mm i.d. x 0.25 μm film thickness). Helium was used as the carrier gas at a linear flow velocity of

32 cm/sec. Effluent from the end of the GC column was split to a 1:1 ratio between the FID and the sniffing port. The oven temperature was held at 45°C for 1.5 minutes, then raised at a rate of 8°C/min for 18.5 minutes, then raised to a rate of 20°C until reaching 325°C for 5 minutes. Integration was done using a HP 3396A Integrator (Hewlett-Packard, Palo Alto, CA, USA).

**Identification of Volatiles**

Volatile compounds were tentatively identified by using Kovats retention index (KI) using a mixture of n-parafins ($C_5$-$C_{40}$) ASTM D2287 Quantitative Calibration Solution in carbon disulfide (Supelco, Bellefonte, PA, USA). KI calculations was made for eluted peaks. Retention indices reported by Cornell University were also used to aid in the identification of compounds by aromas and column types (www.nysaes.cornell.edu/flavornet/).

GC/MS was also used to aid in the identification of volatile compounds on a HP 6890 (Hewlett-Packard, Palo Alto, CA, USA) with 5873 mass selective detector using a HP-5 Trace analysis 5% phenylmethyldisiloxane (15.0m x 250.0 um x 0.25 um film thickness) equipped with a enhanced chemstation version G1701AA Version A.03.00. Helium was the carrier gas. The oven temperature was held at 45°C for 1.5 minutes, then raised at a rate of 8°C/min for 18.5 minutes, then raised to a rate of 20°C until reaching 325°C for 5 minutes.

**Statistics**

A randomized complete block design was used and the data was analyzed by analysis of variance (ANOVA) using SAS (Cary, N.C.) with

tbars=treatment|time|condition as the model statement (SAS, 2003). Means were separated using a Duncan's multiple range test when a significant F-value was obtained.

## RESULTS AND DISCUSSION

This objective of the study was to evaluate the use of poultry collagen coatings, from poultry skins, to prevent oxidation of cat food made with rendered poultry fat. Accelerated shelf-life and ambient conditions were used to determine if oxidation occurred with the addition of poultry fat. The coating to prevent oxidation can help the overall nutrition content of the cat food for the felines, which have very high nutritional requirements in their diets.

### Preliminary Data

#### Composition of Collagen Film from Turkey Skins

41% Moisture, 50% Collagen, 9% other.

#### Composition of Collagen Film from Chicken Skins

40% Moisture, 56% Collagen, 4% other.

#### Poultry Fat

TBARS of 1.52 mg/kg malonaldehyde in rendered poultry fat,

pH of 6.97.

#### Percent Recovery of Chicken Collagen

40%.

#### Percent Recovery of Turkey Collagen

96%.

#### Coverage of Collagen Film on Kibbles

The collagen films were observed by placing food grade dye (red and green) in collagen to observe the overall coating of the collagen coating onto the kibble surface. Also the non dyed kibbles were placed onto a microscope with a black

light to observe the coating for cracks or pits. Coatings were found to have no cracks or other problems.

**Collagen Film and Poultry Fat Influences on Composition**

The composition of the cat food with different fat and collagen applications are reported in Table 4. The Association of American Feed Control Officials (AAFCO) requires a minimum of 30% protein in dry kibble for a feline diet (AAFCO, 2003). The highest protein content was found in the (control) kibble and the treatment with kibble and collagen coating. When fat was applied, the percent protein in the products was reduced proportionally. The treatments with kibble and fat; kibble, fat and collagen; and kibble, fat with tocopherol and collagen coating were similar to one another in gross composition. Kibble with fat with BHA/BHT and collagen coating was significantly different from the control. Differences in the protein content were probably caused by the addition of fat and collagen, α-tocopherol, BHA/BHT which caused the total weights of the kibbles to increase, therefore reducing the relative amount of protein. All treatments had the required amount of protein present, except kibble with fat, BHA/BHT, which was significantly less in protein from the other treatments. This treatment appeared to pick up more fat, causing a greater dilution in the protein content than the kibble with fat and collagen. This may have been due to experimental variability or perhaps the BHA/BHT caused an increased fat pickup.

Difference in the percent ash in the control treatment compared to the experimental treatments was due to the addition of fat and collagen to the kibble that cause an increase in the ash-free weight of the kibble (Table 4).

The differences in the fat percentage can be attributed to the fat coating applied to the kibble with the control treatment and the kibble with collagen coating having much lower fat percentage ($P<0.05$) than the fat coated treatments (Table 4). The AAFCO gives the nutritional requirements for fat within the cat food with a minimum of 10% fat (AAFCO 2003). The control kibble and kibble with only collagen added did not meet the minimum fat requirement. All other treatments with added fat met and exceeded the minimum fat required for a feline diet.

A maximum moisture content of 10% is required for dry cat food to help retard microbial growth and also to give an extended shelf-life (AAFCO, 2003). However, water activity not water content per se is the important factor. The percent moisture in the cat food varied with the addition of fat and collagen coatings (Table 5). On day 0, moisture for kibble with collagen coating was significantly higher ($P<0.05$) than the other treatments and was also higher than the AAFCO maximum level. The high moisture in the kibble with collagen coating could be attributed to absorption of moisture in the collagen by the starch used in the kibble with incomplete drying. By the end of day 8 of storage at jungle conditions, the percent moisture was again significantly different ($P<0.05$) for the kibble and collagen coating having a higher percent moisture than all other treatments. All other collagen-coated treatments also had an additional lipid coating present, which would have protected against moisture migration or dropped the moisture content by dilution (Gennadios, 2002). Moisture levels above 10% can become a problem by promoting mold growth, off-aroma development and a overall reduction of the shelf-life of the product.

Collagen coatings are directly affected by relative humidities that can cause a reduction in the barrier properties of the film. Collagen films have good oxygen barrier properties on food stored in low relative humidity environments (Gennadios et al., 1997). Although collagen films are sensitive to high relative humidities, they can be applied to reduce damage to foods during handling and transportation (Chen, 1995). Collagen films do have some limitations that range from extreme pH ranges, high temperatures and microbiological damage (Maser et al., 1991). Commercially available collagen films from bovine and porcine sources inhibit moisture loss and oxygen transport while providing structural integrity for meat products (Gennadios, 2002). Protein films have a high permeability to polar substances such as water vapor and a low permeability to non-polar substances such as aromas, oils and oxygen (Gennadios, 2002). An increased relative humidity causes a direct increase on the water vapor and oxygen permeability of the collagen film (Gennadio, 2002). Jungle and ambient storage conditions had high (83%) to moderate (51%) relative humidity, respectively, which probably altered the oxygen barrier properties of the collagen.

Percent moisture under ambient storage conditions also was affected by the addition of fats and coatings to the dry pet food kibble (Table 5). At the end of the ambient storage conditions, the moisture content of the collagen-coated kibbles decreased. This could be explained by the collagen coating allowing moisture migration out as well as into the collagen film on the kibble. The drop in moisture might also be due to loss of water from the collagen film while stored under low water activity conditions. The moisture content and water activity of the films was not measured. The control kibble and also the kibble and collagen coating were significantly different ($P<0.05$) from

the other treatments. To achieve a good moisture barrier, the addition of a lipid or wax in addition to the protein film is suggested (Gennadios, 2002).

**Water Activity Influenced by Coating**

Water activity also can affect the overall shelf-life of the dry cat food kibbles and palatability of the product. Water activity is defined equilibrium relative humidity divided by 100 (Nawar, 1985). Water activity is also dependent on temperature (Nawar, 1985). Water activity can have an effect on reaction rates of oxidation and browning reactions (deMan, 1999). Water present in the liquid collagen may have migrated into the kibble and stayed there, at least temporarily, after film drying.

Water activity has a major effect on the texture of foods (deMan, 1999). This could be one reason why the kibble with collagen treatment had a softer texture than all other treatments. The softer texture was noted because the kibbles were very easy to mash giving less resistance than the other treatments.

The kibble with collagen coating (Table 6) had a significantly higher water activity ($P<0.05$) compared to the control kibble, kibble with fat, BHA/BHT and collagen coating and kibble with fat, tocopherol and collagen coating. However, at the end (day 8) of the jungle storage conditions, the control kibble and kibble with collagen had significantly higher water activity ($P<0.05$) from the kibble and fat; kibble with fat, BHA/BHT and collagen coating and kibble with fat, tocopherol and collagen coating. All treatments with coatings had a lower water activity level, at the end than the beginning,

which contrasted with the uncoated control kibble. The lowering of the water activity could be attributed to the equilibration of the kibble to the surrounding humidity.

Water activity was affected also by the ambient storage conditions. On day 30 of the study, the water activities of control kibble was significantly higher ($P<0.05$) than the kibble with fat, BHA/BHT and collagen coating, and kibble with fat, tocopherol and collagen coating. In the ambient storage conditions, all of the water activity of the kibbles decreased during storage as water was lost in the humidity chamber.

The water activity was evaluated for ground kibble rather than whole (Table 7). This was done to evaluate the whole kibble and avoid coating possibly increasing equilibrium time and producing erroneous water activity measurements. On day 0, the water activity of kibble with collagen coating was significantly higher ($P<0.05$) than the control kibble, kibble with fat, and kibble with fat, tocopherol and collagen coating. This supports the explanation that water from the collagen solution was pulled into the starch of the dry kibble and was trapped in the matrix. However, at the end (day 8) of storage at jungle conditions, there were no significant differences in the water activity of the kibble treatments. The control kibble had a higher water activity at the end of the study than at the beginning unlike the other treatments.

Water activities of the ground kibble also were observed at ambient storage conditions (Table 7). At the end of the ambient storage the ground kibble there was no significant difference ($P<0.05$) in water activities among treatments. Because all of the coated treatments had higher water activity at time zero when measured ground rather than whole kibble, it is likely that the coating covered the measured water activity in the samples. Although grinding samples before measurement risks pickup of moisture in

hygroscopic materials, the higher water activities observed in ground samples are probably more accurate.

**Assessment of Oxidation Changes**

Thiobarbituric acid reactive substances (TBARS) were used as a measurement of oxidation of the dry pet food kibble. The TBARS test, is used frequently to evaluate the extent of lipid oxidation in food systems (Nawar, 1985). A secondary product of lipid oxidation is malondialdehyde, a dienal, which can further lead to the development of aldehydes, ketones and epoxides. Malonaldehyde is produced during the termination stage of lipid oxidation.

Poultry meats, especially turkey meat, are highly susceptible to oxidation because of relatively high levels of polyunsaturated fatty acids (PUFA) (Meynier et al., 1999). Processors of turkey skins have been less satisfied in attempts to utilize skin (Thomas et al., 1971). Turkey skins often are used as a source of turkey flavor within a product. However once cooked, the turkey skin rapidly undergoes autoxidation and the product becomes rancid, degrading the flavor (Mecchi et al., 1956). Odor regenerated from turkey skin carbonyls elicited the following responses from an expert taste panel: methyl ketone- oily, minty; alkanal-meaty, turkey-like; alk-2-enal- strong, oxidized, broth-like; alk-2, 4 dienal- strong, painty, nutmeg-like, and spicy (Dimick and MacNeil 1970).

The accelerated shelf life was accomplished using jungle storage conditions, which is 83% RH and 45°C for 8 days. Oxidation was measured at days 0, 2, 4, 6, and 8. The oxidation rates of the kibbles, as measured by TBARS, were low (Figure 1). On day

0, the TBARS in control kibble was significantly higher ($P<0.05$) than the other treatments. The kibble with collagen coating had significantly higher TBARS ($P<0.05$) from the treatment kibble with fat, BHA/BHT and collagen coating. This was likely due to a dilution effect since the poultry fat used had non-detectable TBARS and collagen would not provide malondialdehyde and reduces TBARS by dilution. On day 2, the (control) kibble had significantly higher TBARS values than kibble with fat, kibble with fat and collagen coating, kibble with fat, tocopherol and collagen coating and kibble with fat, BHA/BHT and collagen coating. The kibble with collagen coating treatment was similar to the other treatments. On day 4, again the control kibble had significantly higher TBARS ($P<0.05$) than all other treatments. The kibble with collagen coating treatment and kibble with fat and collagen coating treatments were significantly less oxidized than the kibble with fat treatment. All other treatments were similar. On day 6, the control kibble was significantly more oxidized ($P<0.05$) than the other treatments. On day 8, the control kibble was significantly different again having higher TBARS values than the other treatments. Furthermore, overall the TBARS decreased in value during storage. This might be attributed to the malonaldehyde in the samples reacting with free amine in amino acids. This would cause a decrease in the measurable amount of malonaldehyde in the samples, resulting in lower TBARS values.

The oxidation measurements (TBARS) were also conducted during ambient storage conditions (Figure 2). The ambient study measured oxidation of the treatments over a month period, taking TBARS measurements on week 0, week 1, week 2, week 3, and week 4. At week 0, there was a significant difference ($P<0.05$) with the control kibble having a higher amount of oxidation than the other treatments. At week 1, again

the control kibble had a higher level of oxidation ($P<0.05$), than kibble with fat, kibble with fat and collagen coating, kibble with fat, BHA/BHT and collagen coatings and kibble with fat, tocopherol and collagen coating. The kibble with collagen coating treatment was similar to the other treatments. At week 2, there was a significant difference ($P<0.05$) in the control kibble having a higher TBARS value than the other treatments. All other treatments were the same. At week 3, the control kibble TBARS was significantly higher ($P<0.05$) than the other treatments. All other treatments were the same. At week 4, no significant differences were found among the treatments. By the end of the ambient study, there was a slight trend for an increase in oxidation with all of the treatments. One pet food manufacture stated that dry kibble pet food should have a shelf-life of 12-18 months. Since this study was just a month in length with freshly produced kibble, TBARS should be very low. A longer study might have lead to more significant difference among the treatments over a longer period of time. The differences in relative changes between jungle and ambient storage may be related to the know affect of water activity on maillard browing, a well known carbonyl-amine reaction.

**Contribution of Collagen Film and Poultry Fat to Volatile Aromas**

Gas chromatography-olfactometry was used to compare volatile profiles in relation to contribution of fat, collagen, antioxidants, and possible oxidation products. Aromas and the estimated intensities were assigned to the cat food at the beginning, and end of ambient conditions and jungle storage. On day 0, the aroma profile obtained included thirteen different odor active compounds (Table 8). At the end (day 8) of the

jungle conditions the aroma profile included twenty-three different odor active compounds (Table 9). At the end (day 30) of the ambient conditions of the dry cat foods, the aroma profile included eighteen different odor active compounds (Table 10). Many of the odor active compounds were the same among the aroma profiles. The intensities of the aromas did not significantly increase among storage conditions although the number of compounds determined clearly did.

Volatile compounds had specific aromas that were present at ambient conditions on day 30 that were not present in treatments at day 0. The kibble and fat treatment at ambient storage conditions had volatile compounds that were perceived as musty, earthy, mushroom, and plastic. These aromas were not present in kibble with fat at day 0. Also at day 30, the control kibble had a volatile compound giving an earthy, musty, or roasted at a retention time of 14.35-14.60 and a sweet or vanilla aroma at retention time of 17.28-17.83 that was not present in the control kibble at day 0. Three out of four of the collagen coated treatments at day 30 had a grape aroma at 15.06-15.17 retention time but these aromas were not present at day 0.

Some volatile compounds are specific for treatments in jungle conditions (day 8) when compared to the baseline data day 0. The kibble and fat treatment has a musty or moldy aroma associated with it at the retention time of 1.76-1.78 on day 8 that was not present in the kibble with fat at day 0. A volatile aroma compound in the kibble and collagen treatment at a retention time of 2.80-2.85 had a musty or moldy aroma that was not present at day 0. Also, the odor volatile compounds produced at retention times of 10.52-10.64 on day 8 had an earthy, grassy or vegetable aroma present in the kibble and kibble with fat, which might be an oxidation product. These were not present on day 0.

On day 8, at the retention time of 15.15-15.49, volatile aroma compounds producing grape, floral or fruity which was present in all treatments except the control kibble. These compounds were not present at day 0.

Volatile and aroma compounds identified using GC-MS in the control kibble at the beginning of the study included acetic acid, 3-methyl butanal, hexanal, tetrachloroethylene, 2,2,6,6 pentamethyl heptane, β-myrcene, D-limonene, octadecane, tetracosane, nonadecane, and hexacosane (Figure 3). Some of theses compounds are associated with aroma compounds. Some of the volatile compounds with aromas included: acetic acid-sour or acid like, hexanal-green, grassy or fatty, β-myrcene-sweet, balsamic or plastic, limonene- citrus, sweet or orange. The only volatile compound that corresponds with the GC-O data is β-myrcene which has a sweet balsamic aroma, which is present at day 0, 8 and 30 in certain treatments but not all treatments. Volatile compounds identified in treatment kibble with fat at jungle conditions on day 8 included acetic acid, 3-methyl butanal, hexanal, tetrachloroethylene, 2,2,6,6, pentamethyl heptane, β-myrcene, D-limonene, nonanal, hexadecane, heptadecane, octadecane, eicosane, tetracosane, nonadecane, and hexacosane (Figure 4). The volatile and aroma compounds identified in treatment kibble with fat and collagen coating on day 30, by GC-MS, stored at ambient conditions included acetic acid, 3-methyl butanal, hexanal, tetrachloroethylene, 2,2,6,6, pentamethyl heptane, β-myrcene, D-limonene, nonanal, hexadecane, heptadecane, octadecane, eicosane, tetracosane, nonadecane, and hexacosane (Figure 5). At the beginning of the study there were fewer compounds than at the end of the jungle and ambient conditions. There were no differences in volatile compounds that were produced between the jungle and ambient conditions at the end of

storage. 3-methyl butanal, hexanal, heptanal and nonanal are all aldehydes, which are products of lipid oxidation. The presence of hexanal in the kibble with fat and collagen coating was significantly higher than the control kibble on the GC chromatograms, but the intensity from the GC-O data was not different. Tetracholorethylene is unusual and not expected. The origin of this compound is unknown.

**Changes in Fatty Acid Compositions**

Percentage fatty acids were calculated to determine if a detrimental effect took place during the storage of dry cat food treatments. Poultry fat deposits have a fatty acid composition of 24% C 16:0, 6% C 16:1n-7, 6% C 18:0, 40% C 18:1n-9, 17% C 18:2n-6 and 1% C18:3n-3 (deMan, 1999). Animal fats have been characterized by having 20-30% palmitic acid (deMan, 1999). The only requirements set by the AAFCO require that cat food have a minimum of 1% linoleic (18:2n-6), .5% linolenic (18:3n-3), and .02% arachidonic (20:4n-6), however, there was no minimum or maximum amount on omega-6 fatty acids (AAFCO, 2003). Competition can exist between omega 6 and omega 3 for desaturation and elongation; this includes the formation of archidonic acid in animals. Polyunsaturated fatty acids, with two or more double bonds, can be easily oxidized, causing the loss of essential fatty acids, formation of free radicals and the development of rancid off-flavors and aromas (Bell, 2001). The fatty acid profiles can sometimes provide an indication of oxidative stability (Rhee et al., 1999).

At the beginning of the study, fatty acid percentages were lower for C 16:0 and C 18:2n-6, but higher values were reported for C 17:0 (Table 11). After storage conditions,

both ambient and jungle, there was a trend for higher C 16:0 and C 18:2n-6 percentages, however, there was a decrease in C 17:0 values (Table 12 and 13). All other fatty acid percentages were similar to one another from beginning to the end of both storage conditions. One reason for the lower values in the beginning of the fatty acid percentages might be that the fatty acids were stored at -10°C before being analyzed instead of being stored at –70 °C like the samples removed from storage. This could have caused detrimental effects on the fatty acids that were stored the longer period of time at the highest temperature.

Meynier and others (1999) have linked the oxidation of fatty acids to certain volatile compounds. Fatty acid oxidation of ω6 produces compounds such as 1-octen-3-ol, 1-octen-3-one, E-2-heptenal and hexanal, which has been shown to be a major volatile compound (Meynier et al., 1999). Also oxidation of ω9 fatty acids can produce saturated aldehydes like nonanal (Meynier et al., 1999). All the treatments had similar percent fatty acid compositions, including the treatments with added rendered poultry fat. EPA was also present in the fatty acid composition which may have been caused by the addition of fish meal into the cat food formulation. Because oxidation did not occur at high levels in any of the stored samples, a longer storage period would be needed to determine conclusively if the collagen barrier can serve as a preventative barrier against oxidation.

The use of poultry collagen could be a favorable asset to the poultry industry by utilizing poultry by-products (skins). Collagen films could be a key in the reduction to oxidation in pet foods and also might aid in a prolonged shelf-life of the pet food. Collagen films are suspended into an acidic solution and this can cause an increase in the

aroma profile of acetic acid in the collagen coated treatments. However, the coated food had a more shiny appearance and was less susceptible to damage and dust formulation.

Collagen coatings can be used to help protect the essential nutrients that are present in cat food. Since pet foods have to be nutritionally balanced to provide an adequate diet for felines, oxidation can greatly impact the nutritional components of cat food. Essential fatty acids are provided by cat food and are not produced by the feline diet. These nutrients are very important to remain in adequate levels to ensure the health of the felines by the diet provided.

## CONCLUSIONS

The treatments that were observed had some similar trends that were apparent in the study. Overall most of the chemical analysis on the six treatments was effected by the dilution of poultry fat and collagen coatings applied to the kibbles. Since most of the chemical analysis are measured on a weight basis. TBARS were significantly higher for the control kibble than all other treatments over time and condition. Water activities were dependent on the addition of fat and collagen added to the kibbles. The collagen coating could have attributed to a higher water activity of the treatment kibble with collagen, by some water being present in the solution and the starch in the kibbles could have attributed to bound water in the kibbles. The fat coating seemed to help contribute to the overall appearance of the kibbles giving a very shiny appearance to them. Little oxidation seemed to have occurred over time and treatments, this is observed by TBARS and also in the aroma profiles.

Further research would be needed to determine if collagen actually works as a protective barrier against oxidation, therefore, a longer time frame should be used to observe oxidation. One article concluded that the cat food did not start oxidizing until after being stored for nine months. Collagen barrier properties of films and oxidation might be a key link to observing if collagen coatings are good barriers against moisture migration and oxidation.

There were more aroma active compounds in the collagen-coated treatments than the non-coated treatments. Some of the volatile compounds contributing to the overall aroma profile may have a masking affect the good aromas such as meaty, which could affect the palatability of the dry cat food kibbles. Also further research could be

conducted to provide information if collagen films have the properties to be good aroma barriers.

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**Table 4. Composition of Cat Food by Treatments on a Wet Weight Basis**

| Treatments | % Protein[1,2] | % Ash[1,2] | % Fat[1,2] |
|---|---|---|---|
| Kibble (control)[3] | 50.4a | 7.2a | 5.4b |
| Kibble with Fat | 32.8bc | 5.0b | 44.5a |
| Kibble with Collagen Coating | 40.6ab | 5.2b | 8.8b |
| Kibble with Fat and Collagen Coating | 32.2bc | 4.7b | 42.3a |
| Kibble with Fat, BHA/BHT and Collagen Coating | 24.9c | 4.6b | 53.9a |
| Kibble with Fat, Tocopherol and Collagen Coating | 31.2bc | 4.7b | 45.5a |

[1] N=3 replications
[2] Means with different letters within columns are significantly different ($P<0.05$)
[3] Uncoated kibble was obtained from Ralston Purina (St. Lois, MO)

**Table 5. Percent Moisture of Cat Food at Beginning and End of Storage at Jungle and Ambient Conditions**

| Treatments | Baseline[1,2] % Moisture | Jungle [1,2,3] % Moisture | Ambient[1,2,4] % Moisture |
|---|---|---|---|
| Kibble (control) | 6.11b | 9.53b | 9.03a |
| Kibble with Fat | 4.12b | 6.67b | 5.76b |
| Kibble with Collagen Coating | 22.5a | 15.5a | 10.3a |
| Kibble with Fat and Collagen Coating | 8.57b | 8.55b | 6.03b |
| Kibble with Fat, BHA/BHT and Collagen Coating | 11.8b | 8.64b | 6.32b |
| Kibble with Fat, Tocopherol and Collagen Coating | 9.28b | 8.53b | 6.57b |

[1] N=3 replications
[2] Means with different letters within a column are significantly different ($P<0.05$)
[3] 42°C and 83% relative humidity, Day 8
[4] 21°C and 51% relative humidity, Day 30

**Table 6. Water Activities of Cat Food Whole at Beginning and End of Storage at Jungle and Ambient Conditions**

| Treatments | Baseline Aw[1,2] | Jungle Aw[1,2,3] | Ambient Aw[1,2,4] |
|---|---|---|---|
| Kibble (control) | .565b | .587a | .558a |
| Kibble with Fat | .673ab | .527b | .502bc |
| Kibble with Collagen Coating | .760a | .655a | .532ab |
| Kibble with Fat and Collagen Coating | .626ab | .543ab | .490bc |
| Kibble with Fat, BHA/BHT and Collagen Coating | .616b | .533b | .478c |
| Kibble with Fat, Tocopherol and Collagen Coating | .611b | .509b | .467c |

[1] N=3 replications

[2] Means with different letters within a column are significantly different ($P<0.05$)

[3] 42°C and 83% relative humidity, Day 8

[4] 21°C and 51% relative humidity, Day 30

**Table 7. Water Activites of Cat Food Ground at Beginning and End of Storage at Jungle and Ambient Conditions**

| Treatments | Baseline Aw[1,2] | Jungle Aw[1,2,3] | Ambient Aw[1,2,4] |
|---|---|---|---|
| Kibble (control) | .587b | .611a | .588a |
| Kibble with Fat | .603b | .557a | .526a |
| Kibble with Collagen Coating | .835a | .726a | .583a |
| Kibble with Fat and Collagen Coating | .693ab | .662a | .536a |
| Kibble with Fat, BHA/BHT and Collagen Coating | .688ab | .647a | .560a |
| Kibble with Fat, Tocopherol and Collagen Coating | .662b | .623a | .571a |

[1] N=3 replications

[2] Means with different letters within a column are significantly different ($P<0.05$)

[3] 42°C and 83% relative humidity, Day 8

[4] 21°C and 51% relative humidity, Day 30

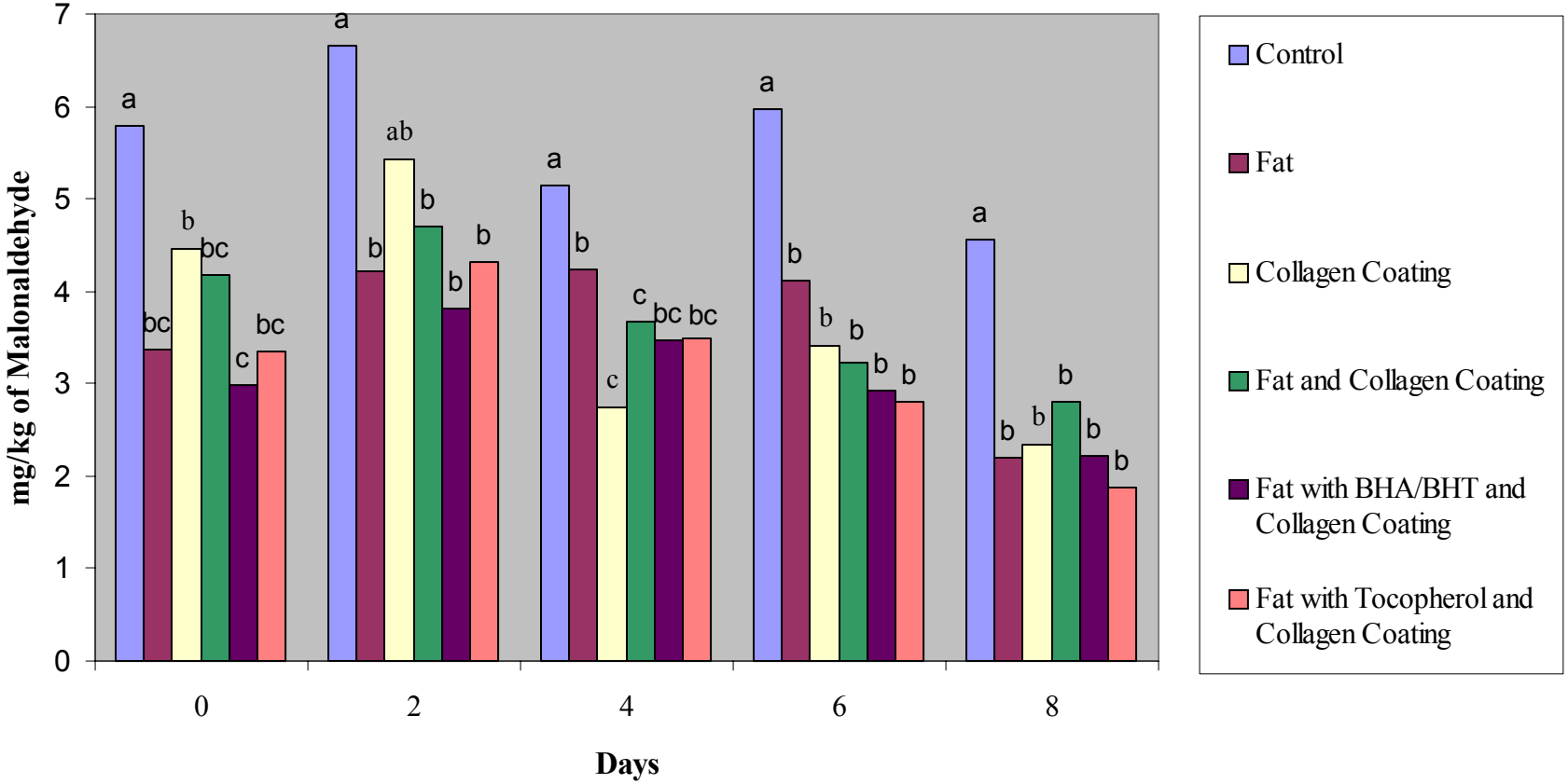


Figure 1. Oxidation (TBARS) of Cat Food on the Basis of Treatment and Time at Jungle Conditions (42°C and 83% relative humidity). Different letters within each set of columns represents significant differences ($P<0.05$).

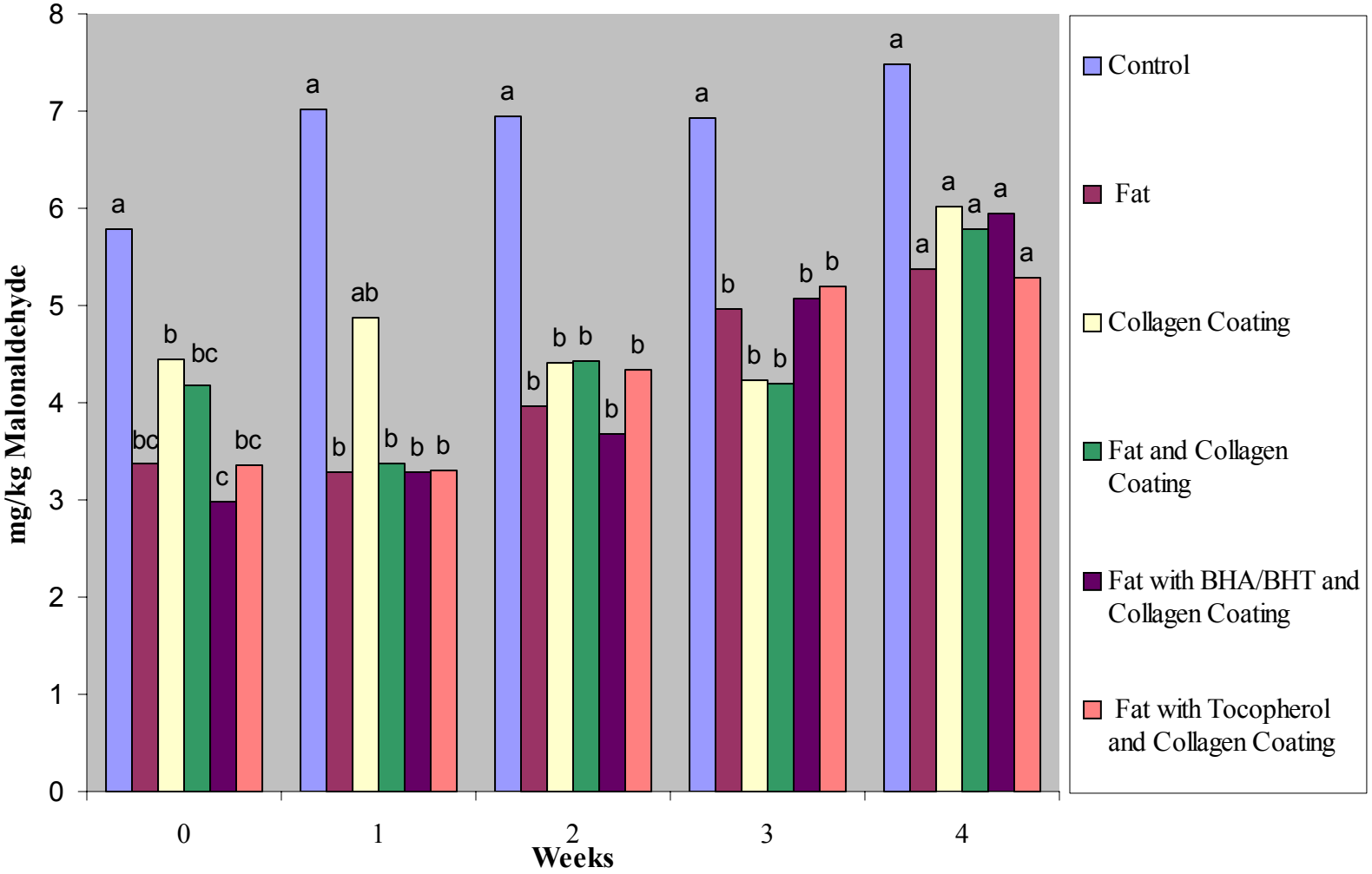


Figure 2. Oxidation (TBARS) of Cat Food on the Basis of Treatment and Time at Ambient Conditions (21°C and 51% relative humidity). Different letters within each set of columns represents significant differences ($P<0.05$).

**Table 8. Aromas and Estimated Intensity in Cat Food by Treatment on Day 0[1,2,3,4]**

| RT | Aroma | Treatments | Trt 1 | Trt 2 | Trt 3 | Trt 4 | Trt 5 | Trt 6 |
|---|---|---|---|---|---|---|---|---|
| 2.12-2.52 | acetic acid/sour/acidic | 4,5,6 | --- | --- | --- | 1.5 | 1.5 | 1.5 |
| 4.38-4.61 | cheesy/rancid/butyric acid | 3,4,5,6 | --- | --- | 1.2 | 1.6 | 1.4 | 1.5 |
| 4.61-4.73 | grassy/green | 3,4,5,6 | --- | --- | 1.0 | 1.0 | 1.0 | 1.3 |
| 5.28-5.43 | cheesy/rancid | 1,3,6 | 1.2 | --- | 1.5 | --- | --- | 1.3 |
| 5.60-5.65 | musty/moldy/earthy | 1,2,3,4,5,6 | 1.5 | 1.3 | 2.0 | 1.9 | 1.3 | 1.3 |
| 5.92-6.15 | nutty/sweet/baked/almond | 3 | --- | --- | 1.4 | --- | --- | --- |
| 6.67-6.85 | chromium picolinate/cat food/meaty | 1,2,3,4,5,6 | 1.9 | 1.7 | 1.9 | 2.1 | 1.7 | 1.8 |
| 7.05-7.21 | nutty/sweet/baked/floral | 1,2,3,6 | 1.3 | 1.6 | 2.3 | --- | --- | 1.3 |
| 8.38-8.57 | earthy/musky/mushrooms/sulfurous/grassy/metallic | 1,3,4,5,6 | 1.3 | --- | 1.4 | 1.4 | 1.5 | 1.3 |
| 9.02-10.02 | sweet/balsamic | 3,4 | --- | --- | 1.2 | 1.1 | --- | --- |
| 10.59-10.65 | meaty/nutty | 2 | --- | 1.8 | --- | --- | --- | --- |
| 11.11-11.5 | sweet/baked/caramel/floral/green | 3,5 | --- | --- | 1.9 | --- | 1.0 | --- |
| 12.12-12.27 | earthy/musty/moldy/woody/ethereal | 1,3,4,6 | 1.3 | --- | 1.2 | 1.2 | --- | 1.3 |

[1] Treatment 1-control, Treatment 2-with fat, Treatment 3- with collagen, Treatment 4-with fat and collagen, Treatment 5-with fat, BHA/BHT and collagen, Treatment 6-with fat, tocopherol and collagen

[2] RT- retention time from the gas chromatograms, range of retention times are to accommodate the varied times from chromatograms and allows for grouping of like compounds

[3] Scale for intensity of aromas 1- slight to 5-very potent

[4] Means calculated for intensity values, n=3

**Table 9. Aromas and Estimated Intensity in Cat Food by Treatment after 8 days Storage at Jungle Conditions[1,2,3,4,5]**

| RT | Aroma | Treatments | Trt 1 | Trt 2 | Trt 3 | Trt 4 | Trt 5 | Trt 6 |
|---|---|---|---|---|---|---|---|---|
| 1.76-1.78 | musty/moldy | 2 | --- | 1.5 | --- | --- | --- | --- |
| 1.94-2.57 | acetic acid/acidic/sour | 1,3,4,5,6 | 1.1 | --- | 1.8 | 1.6 | 1.9 | 2.1 |
| 2.60-2.70 | roasted/feed/nutty | 2,4 | --- | 1.7 | --- | 1.8 | --- | --- |
| 2.70-2.75 | rancid/cheesy/sulfurous | 3 | --- | --- | 2.5 | --- | --- | --- |
| 2.80-2.85 | musty/moldy | 3,5 | --- | --- | 1.3 | --- | 1.3 | --- |
| 4.31-4.57 | rancid/cheesy | 1,2,3,4,5,6 | 1.7 | 1.3 | 2.1 | 2.0 | 2.0 | 1.9 |
| 4.58-4.70 | grassy/green | 1,2,3,5,6 | 1.0 | 1.8 | 1.9 | --- | 1.4 | 1.6 |
| 5.40-5.49 | musty/cheesy/rancid/old shoes | 1,2,3,4,5,6 | 1.6 | 1.6 | 2.5 | 2.2 | 1.7 | 1.8 |
| 5.60-5.75 | musty/moldy | 3 | --- | --- | 1.5 | --- | --- | --- |
| 6.00-6.19 | sweet/roasted/baked/nutty | 6 | --- | --- | --- | --- | --- | 1.0 |
| 6.60-6.89 | vitamins/meaty/chromium picolinate/potato chips | 1,2,3,4,5,6 | 2.1 | 1.8 | 2.1 | 2.1 | 1.8 | 2.1 |
| 7.07-7.22 | nutty/baked/fritos/coffee | 1,2,4,5,6 | 1.4 | 1.8 | --- | 1.3 | 1.2 | 1.4 |
| 8.34-8.48 | mushrooms/sulfurous/metallic/dirt | 4 | --- | --- | --- | 1.4 | --- | --- |
| 8.44-8.70 | plastic/rubbery | 2,4,5 | --- | 1.4 | --- | 1.5 | 1.7 | --- |
| 10.02-10.29 | sweet/earthy/feed | 1 | 1.4 | --- | --- | --- | --- | --- |
| 10.52-10.64 | earthy/grassy/vegetable | 1,2 | 1.0 | 1.2 | --- | --- | --- | --- |
| 10.76-10.84 | woody/roasted/nutty/fatty | 1,4,5 | 1.7 | --- | --- | 1.3 | 1.5 | --- |
| 10.94-11.05 | sweet/caramel/phenolic | 1,2,3,4,5,6 | 1.7 | 1.7 | 1.1 | 1.2 | 1.5 | 1.8 |
| 11.09-11.59 | nutty/roasted/feed/cooked cereal | 2,6 | --- | 1.2 | --- | --- | --- | 1.3 |
| 12.17-12.30 | baked/earthy/woody | 3,6 | --- | --- | 1.3 | --- | --- | 1.3 |
| 12.30-12.37 | nutty/earthy/floral/phenolic | 4 | --- | --- | --- | 1.75 | --- | --- |
| 15.15-15.49 | grapes/floral/fruity | 2,3,4,5,6 | --- | 1.0 | 1.3 | 1.4 | 1.0 | 1.3 |
| 15.37-15.57 | floral/fruity/berry | 3 | --- | --- | 1.25 | --- | --- | --- |

[1] Treatment 1-control, Treatment 2-with fat, Treatment 3- with collagen, Treatment 4-with fat and collagen, Treatment 5-with fat, BHA/BHT and collagen, Treatment 6-with fat, tocopherol and collagen

[2] RT- retention time from the gas chromatograms, range of retention times are to accommodate the varied times from chromatograms and allows for grouping of like compounds

[3] Scale for intensity of aromas 1- slight to 5-very potent

[4] Means calculated for intensity values, n=3

[5] 42°C, 83% relative humidity

**Table 10. Aromas and Estimated Intensities in Cat Food by Treatment after 30 days Storage at Ambient Conditions[1,2,3,4,5]**

| RT | Aroma | Treatments | Trt 1 | Trt 2 | Trt 3 | Trt 4 | Trt 5 | Trt 6 |
|---|---|---|---|---|---|---|---|---|
| 1.76-1.86 | musty/earthy/mushrooms | 2 | --- | 1.0 | --- | --- | --- | --- |
| 1.99-2.29 | plastic | 2 | --- | 1.2 | --- | --- | --- | --- |
| 2.26-2.64 | acetic acid/acidic/sour | 3,4,5,6 | --- | --- | 1.6 | 1.5 | 1.2 | 1.0 |
| 2.61-2.71 | roasted/feed/grain | 3,4,6 | --- | --- | 1.8 | 1.9 | --- | 1.4 |
| 4.40-4.55 | cheesy/rancid/stinky feet | 1,2,3,4,5,6 | 1.7 | 1.9 | 1.8 | 1.9 | 1.0 | 1.7 |
| 4.50-4.69 | grassy/cooked | 2,3,4,5 | --- | 1.7 | 1.5 | 1.4 | 1.0 | --- |
| 5.31-5.53 | musty/rancid/stinky feet/wet dog/pungent | 1,2,3,4,5,6 | 2.2 | 2.1 | 1.8 | 1.7 | 1.6 | 2.1 |
| 6.02-6.09 | cooked/nutty/baked/roasted | 2,3,4 | --- | 1.5 | 1.2 | 1.6 | --- | --- |
| 6.65-6.90 | potato chips/vitamins/roasted/chromium picolinate | 1,2,3,4,5,6 | 2.6 | 2.6 | 2.5 | 2.4 | 2.0 | 2.4 |
| 7.03-7.23 | roasted/nutty/fritos | 1,2,3,4,5,6 | 1.8 | 1.6 | 1.0 | 1.8 | 1.8 | 1.3 |
| 8.36-8.46 | mushrooms/musty/chemically/plastic/sulfurous/metallic | 2,3,4,6 | --- | 1.7 | 1.9 | 2.2 | --- | 1.8 |
| 10.05-10.56 | sweet/baked | 5 | --- | --- | --- | --- | 1.0 | --- |
| 10.67-10.76 | earthy/chocolate/coffee/roasted/baked | 2,4,6 | --- | 1.6 | --- | 1.4 | --- | 1.5 |
| 10.76-11.16 | sweet/nutty/baked/caramel | 3,4,5 | --- | --- | 1.0 | 1.3 | 1.3 | --- |
| 12.20-12.25 | earthy/baked/moldy/musty/woody | 1,2,3,4,6 | 1.5 | 1.3 | 1.1 | 1.0 | --- | 1.3 |
| 14.35-14.60 | earthy/musty/stinky feet/roasted | 1 | 1.0 | --- | --- | --- | --- | --- |
| 15.06-15.17 | Grape | 3,5,6 | --- | --- | 1.1 | --- | 1.1 | 1.3 |
| 17.28-17.83 | sweet/vanilla | 1 | 1.0 | --- | --- | --- | --- | --- |

[1] Treatment 1-control, Treatment 2-with fat, Treatment 3- with collagen, Treatment 4-with fat and collagen, Treatment 5-with fat, BHA/BHT and collagen, Treatment 6-with fat, tocopherol and collagen

[2] RT- retention time from the gas chromatograms, range of retention times are to accommodate the varied times from chromatograms and allows for grouping of like compounds

[3] Scale for intensity of aromas 1- slight to 5-very potent

[4] Means calculated for intensity values, n=3

[5] 21°C, 51% relative humidity

**Table 11. Percent Fatty Acids Present in Cat Food by Treatment at Day 0 for Ambient[1] and Jungle[2] Storage Conditions**

| Fatty Acid Common Names | Shorthand Description | Kibble | Kibble with Fat | Kibble with Collagen | Kibble with Fat and Collagen | Kibble with Fat, BHA/BHT and Collagen | Kibble with Fat, tocopherol and Collagen |
|---|---|---|---|---|---|---|---|
| **Myristic** | **C 14:0** | 0.4 | 0.4 | 1.5 | 0.3 | 2.0 | 0.3 |
| **Myristoleic** | **C 14:1n-5** | 0.1 | 0.1 | 0.5 | 0.1 | 0.1 | 0.9 |
| | **C 15:0** | 0.0 | 0.0 | 0.2 | 1.3 | 1.6 | 1.1 |
| **Palmitic** | **C16:0** | 11.6 | 13.3 | 13.7 | 13.7 | 13.2 | 12.8 |
| **Palmitoleic** | **C 16:1n-7** | 1.9 | 3.2 | 3.0 | 2.2 | 4.7 | 3.9 |
| **Margaric** | **C 17:0** | 30.8 | 31.7 | 30.4 | 31.1 | 32.1 | 28.9 |
| | **C 17:1n-8** | 0.1 | 0.1 | 0.2 | 1.0 | 0.4 | 1.3 |
| **Stearic** | **C 18:0** | 13.6 | 16.8 | 15.9 | 17.4 | 16.5 | 14.4 |
| **Oleic** | **C 18:1n-9** | 25.6 | 26.9 | 26.2 | 24.8 | 24.8 | 27.0 |
| **Linoleic** | **C 18:2n-6** | 3.8 | 3.9 | 3.0 | 3.9 | 3.3 | 3.7 |
| **Linolenic** | **C 18:3n-3** | 0.3 | 0.3 | 1.7 | 0.9 | 0.1 | 0.1 |
| **y-Linolenic** | **C 18:3n-6** | 3.2 | 1.3 | 1.3 | 1.4 | 0.4 | 0.4 |
| **Arachidic** | **C 20:0** | 5.6 | 0.5 | 0.6 | 0.6 | 0.3 | 4.6 |
| **EPA** | **C 20:5n-3** | 0.3 | 0.1 | 0.8 | 0.1 | 0.1 | 0.1 |
| **Behenic** | **C 22:0** | 0.7 | 1.0 | 0.1 | 1.2 | 0.1 | 0.1 |
| | **C 22:1** | 0.3 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | **C 24:0** | 1.1 | 0.1 | 0.5 | 0.0 | 0.3 | 0.3 |
| | **C 24:1** | 0.6 | 0.3 | 0.2 | 0.0 | 0.0 | 0.1 |

[1] 21°C, 51% relative humidity
[2] 42°C, 83% relative humidity

**Table 12. Percent Fatty Acids Present in Cat Food by Treatment on Day 30 of Ambient[1] Storage Conditions**

| Fatty Acid Common Names | Shorthand Description | Kibble | Kibble with Fat | Kibble with Collagen | Kibble with Fat and Collagen | Kibble with Fat, BHA/BHT and Collagen | Kibble with Fat, tocopherol And Collagen |
|---|---|---|---|---|---|---|---|
| **Myristic** | **C 14:0** | 1.4 | 1.0 | 1.3 | 0.9 | 0.8 | 0.7 |
| **Myristoleic** | **C 14:1n-5** | 0.1 | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 |
| | **C 15:0** | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Palmitic** | **C16:0** | 22.7 | 22.6 | 21.7 | 22.8 | 21.5 | 25.3 |
| **Palmitoleic** | **C 16:1n-7** | 6.2 | 5.3 | 6.0 | 0.2 | 9.7 | 2.3 |
| **Margaric** | **C 17:0** | 0.0 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| | **C 17:1n-8** | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 |
| **Stearic** | **C 18:0** | 14.3 | 15.2 | 15.2 | 34.1 | 19.1 | 25.5 |
| **Oleic** | **C 18:1n-9** | 28.4 | 28.4 | 27.2 | 22.2 | 17.4 | 26.4 |
| **Linoleic** | **C 18:2n-6** | 22.8 | 22.8 | 25.9 | 16.6 | 29.0 | 17.7 |
| **Linolenic** | **C 18:3n-3** | 0.0 | 0.0 | 0.1 | 0.6 | 0.1 | 0.2 |
| **y-Linolenic** | **C 18:3n-6** | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 0.8 |
| **Arachidic** | **C 20:0** | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 |
| **EPA** | **C 20:5n-3** | 1.9 | 1.9 | 0.2 | 0.2 | 0.3 | 0.2 |
| **Behenic** | **C 22:0** | 0.3 | 0.3 | 0.2 | 0.2 | 0.1 | 0.0 |
| | **C 22:1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **C 24:0** | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | **C 24:1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

[1] 21°C, 51% relative humidity

**Table 13. Percent Fatty Acids Present in Cat Food by Treatment at Day 8 of Jungle[1] Storage Conditions**

| Fatty Acid Common Names | Shorthand Description | Kibble | Kibble with Fat | Kibble with Collagen | Kibble with Fat and Collagen | Kibble with Fat, BHA/BHT and Collagen | Kibble with Fat, tocopherol and Collagen |
|---|---|---|---|---|---|---|---|
| **Myristic** | **C 14:0** | 1.2 | 1.0 | 1.1 | 0.8 | 1.0 | 0.8 |
| **Myristoleic** | **C 14:1n-5** | 0.2 | 0.2 | 0.1 | 0.3 | 0.4 | 0.3 |
| | **C 15:0** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Palmitic** | **C16:0** | 19.8 | 24.6 | 17.9 | 25.7 | 30.4 | 25.7 |
| **Palmitoleic** | **C 16:1n-7** | 5.7 | 7.8 | 4.9 | 5.6 | 9.1 | 8.6 |
| **Margaric** | **C 17:0** | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 |
| | **C 17:1n-8** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Stearic** | **C 18:0** | 25.7 | 18.2 | 27.6 | 37.2 | 27.3 | 31.5 |
| **Oleic** | **C 18:1n-9** | 25.6 | 25.6 | 28.4 | 16.7 | 18.3 | 10.7 |
| **Linoleic** | **C 18:2n-6** | 18.4 | 19.4 | 16.8 | 11.5 | 10.5 | 19.5 |
| **Linolenic** | **C 18:3n-3** | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.6 |
| **y-Linolenic** | **C 18:3n-6** | 0.7 | 0.9 | 0.8 | 0.3 | 0.7 | 0.5 |
| **Arachidic** | **C 20:0** | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 |
| **EPA** | **C 20:5n-3** | 1.2 | 0.6 | 1.0 | 0.3 | 0.3 | 0.2 |
| **Behenic** | **C 22:0** | 0.1 | 0.1 | 0.1 | 0.1 | 0.4 | 0.3 |
| | **C 22:1** | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 |
| | **C 24:0** | 0.0 | 0.5 | 0.3 | 0.3 | 0.1 | 0.3 |
| | **C 24:1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |

[1]42°C, 83% relative humidity

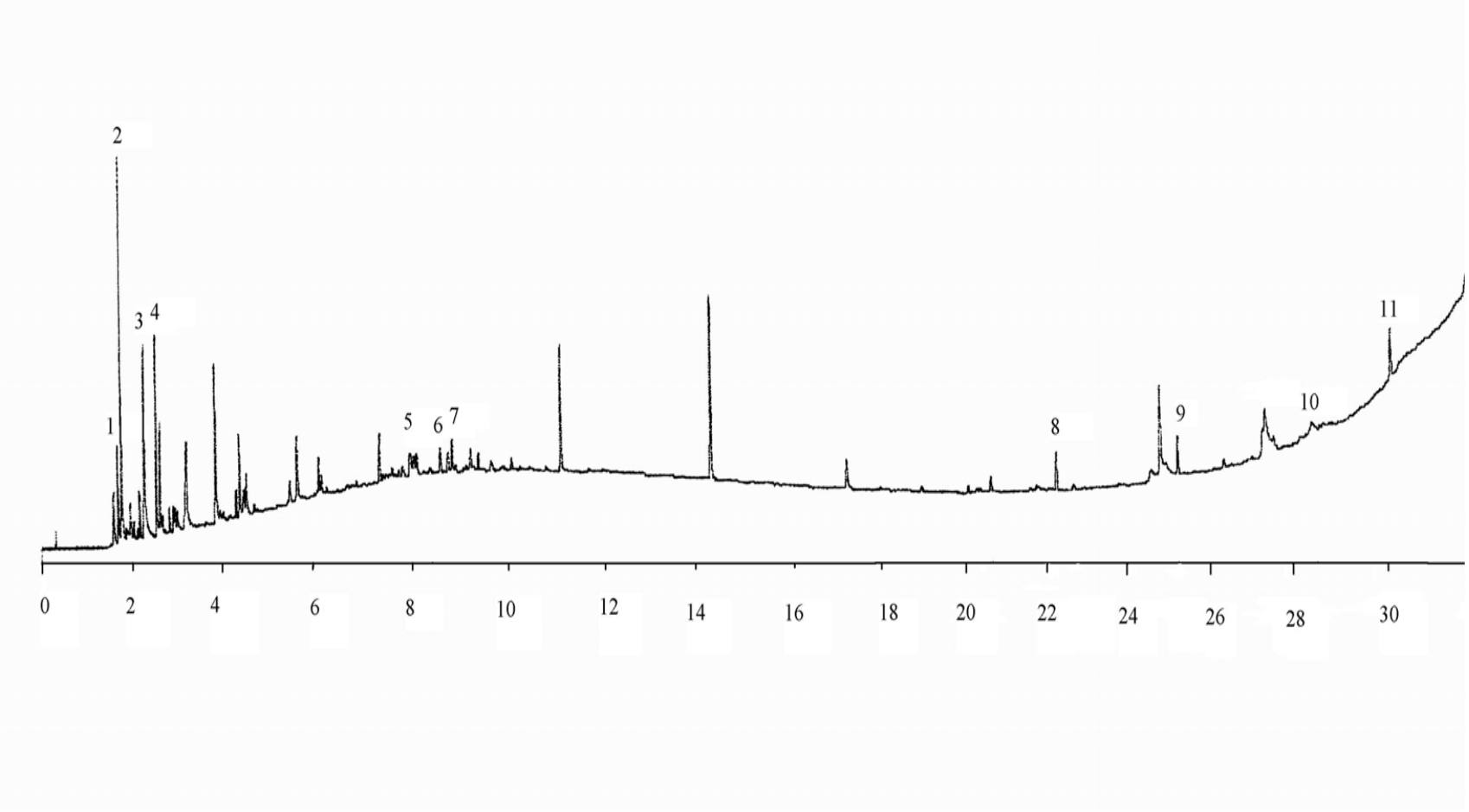


**Figure 3.** Volatile and Aroma Compounds Identified in Control at Day 0 of Ambient (21°C, 51% RH) and Jungle Conditions (42°C, 83% RH). These compounds were identified as: 1. acetic acid, 2. 3-methyl butanal, 3. hexanal, 4. tetrachloroethylene, 5. heptane 2,2,6,6, pentamethyl, 6. β-myrcene, 7. D-limonene, 8. octadecane, 9. tetracosane, 10. nonadecane, 11. hexacosane.

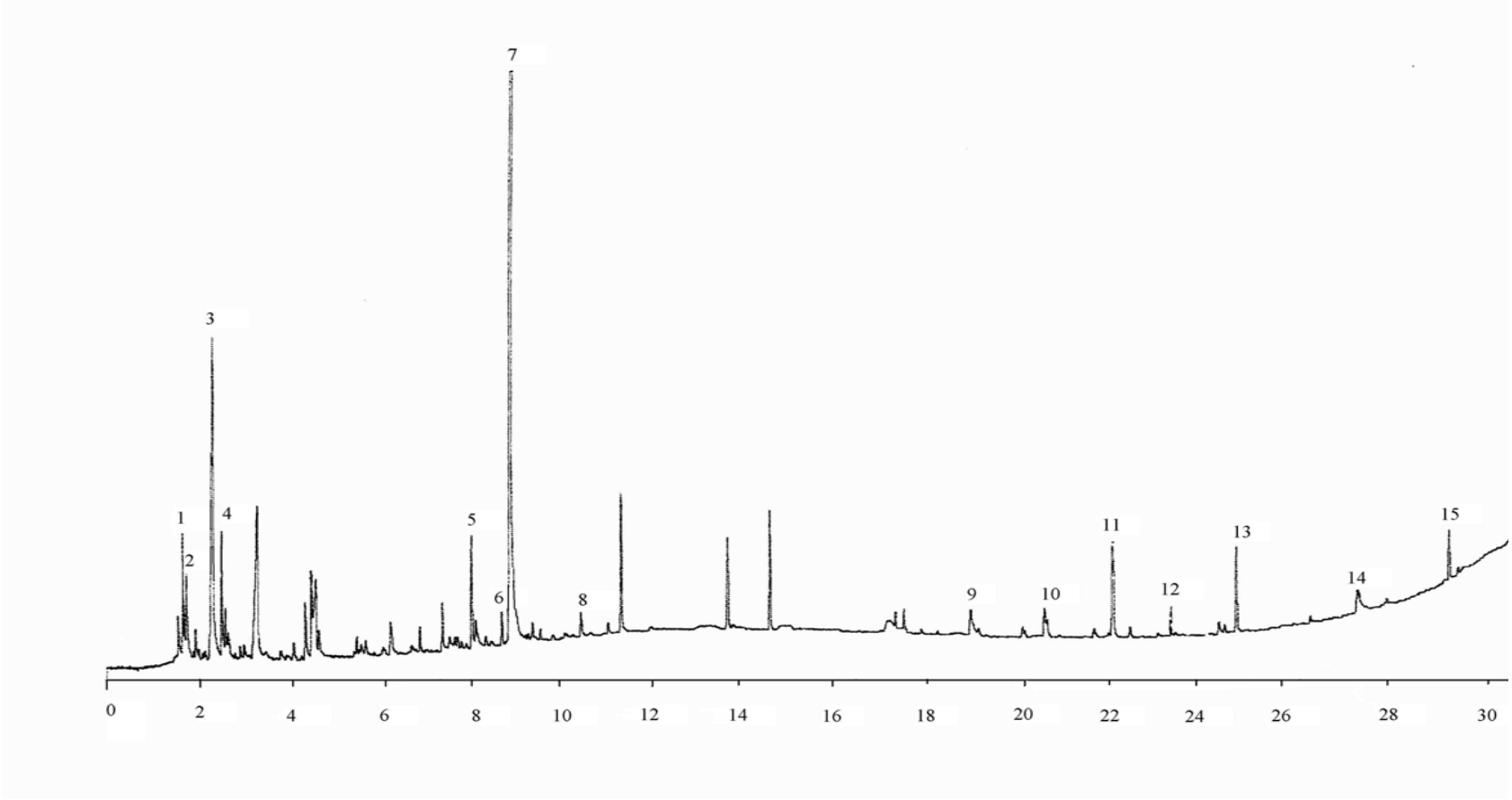


**Figure 4.** Volatile and Aroma Compounds Identified in the Kibble with Fat Treatment on Day 8 Stored at Jungle Conditions (42°C, 83% RH).These compounds were identified as: 1. acetic acid, 2. 3-methyl butanal, 3. hexanal, 4. tetrachloroethylene, 5. heptane 2,2,6,6 pentamethyl, 6. β-myrcene, 7. D-limonene, 8. nonanal, 9. hexadecane, 10. heptadecane, 11. octadecane, 12. eicosane, 13. tetracosane, 14. nonadecane, 15. hexacosane

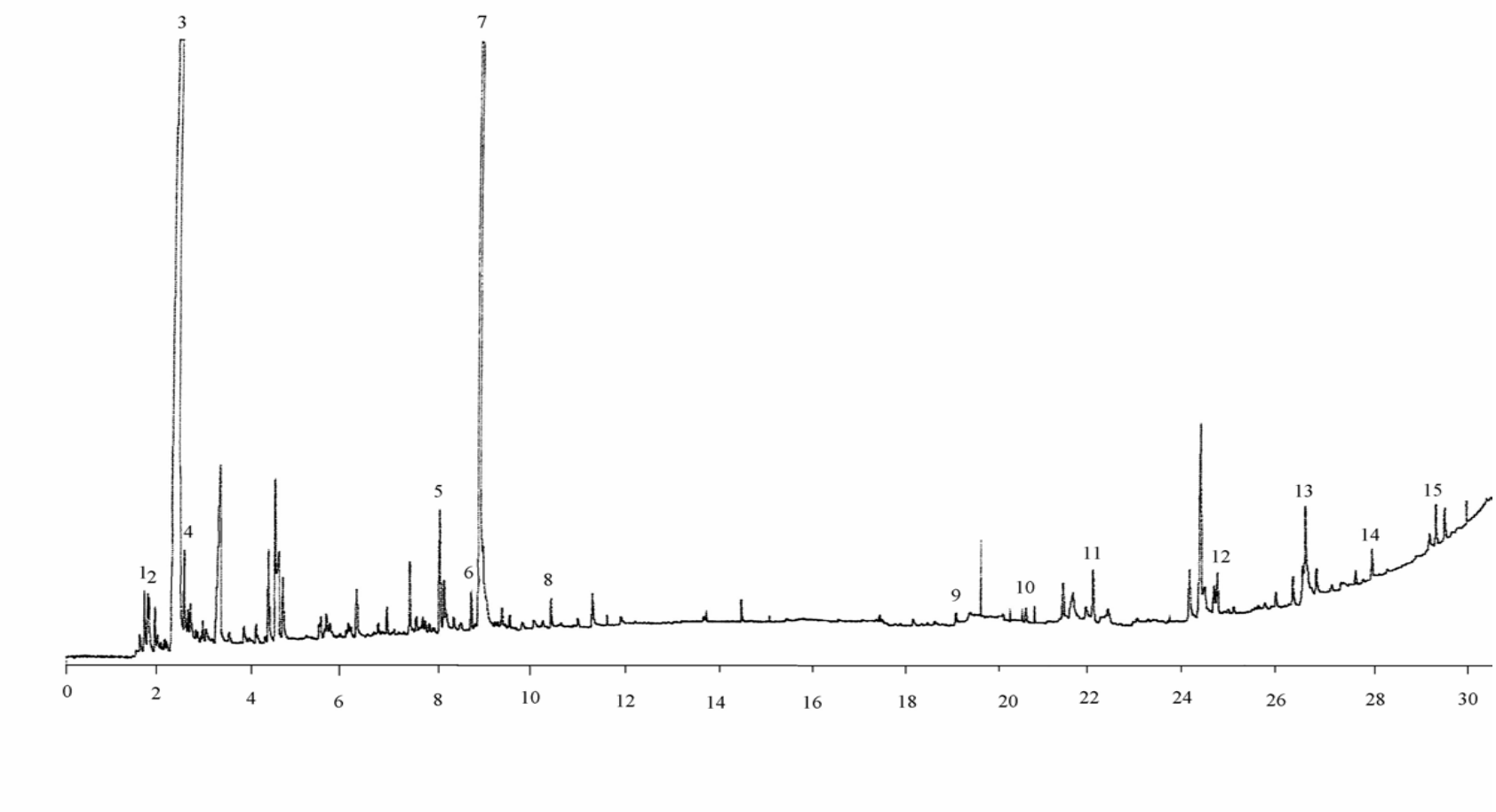


**Figure 5.** Volatile and Aroma Compounds Found in the Kibble with Fat and Collagen Coating Treatment Day 30 Stored at Ambient Conditions (21°C, 51% RH). These Compounds were Identified as: 1.acetic acid, 2. 3-methyl butanal, 3. hexanal, 4. tetrachloroethylene, 5. heptane 2,2,6,6 pentamethyl, 6. β-myrcene, 7. D-limonene, 8. octadecane, 9. hexadecane, 10. heptadecane, 11. octadecane, 12. eicosane, 13. tetracosane, 14. nonadecane 15. hexadecane.

## APPENDIX A

| Major Category | Minor Category | | |
|---|---|---|---|
| **Balsamic** | Carmel | Chocolate | Sweet |
| | Vanilla | Anise | Honey/maple syrup |
| **Camphorous** | | | |
| **Citrus** | Lemon | Lime | |
| **Coffee** | | | |
| **Earthy** | Woody | Rooty | Viney |
| **Ethereal** | Mushroom | Moss | |
| **Fatty** | Butter | Cheese | Creamy |
| | Oily | Sour | Waxy |
| **Floral** | Blossom | Carnation | Other |
| | Geranium | Hyacinth | Gardenia |
| | Jasmine | Lilac | Iris |
| | Rose | Marigold | Violet |
| **Fruity** | Apple | Berry | Grape |
| | Apricot | Raspberry | Pineapple |
| | Cherry | Peach | Melon |
| | Strawberry | Banana | Coconut |
| | Pear | Plum | |
| **Green** | Grassy | | |
| **Herbaceous** | Caraway | Clove | Sage |
| **Meaty** | Boiled Poultry | Clams | Egg |
| **Medicinal** | | | |
| **Minty** | | | |
| **Musty** | Moldy odor | Musky | |
| **Nutty** | Almond | Hazelnut | Walnut |
| | Peanut Butter | Peanut | |
| **Rubbery** | Rubber | Plastic | |
| **Soapy** | | | |
| **Spicy** | | | |
| **Sulfurous** | Metallic | Ammonia | |
| **Vegetable** | Cabbage | Potato chips | Celery |
| | Cucumber | Raw potato | |
| **Wine-like** | | | |
| **Mega Stinky** | Pungent | Sour | Urine-like |
| | Fecal/putrid | Sweat | |
| **Baked Aroma** | Roasted | Cereal | Baked bread |
| **Burnt Aroma** | burnt fat | burnt odor | |

## APPENDIX B

Extraction of Collagen

1. Obtain poultry skins from manufacturer
2. Scrap off excess fat from skins (inside and outside of skin)
3. Cut skins into small pieces
4. Place skins in acetone to de-fat for 10 minutes
5. Remove skins from acetone, then rinse with deionized water three times
6. Then, soak skins in 10% NaCl solution at 4°C for 24 hours
7. After the 24 hours the skins were removed from the solution and rinsed three times with deionized water
8. Then placed in citrate buffer solution with a pH of 4.3 for 48 hours
9. Skins were rinsed three times with deionized water
10. Then placed in a Kitchen-Aide grinder to grind up the skins
11. 500 mL of HCl solution with a pH of 2.5 was added to each 10 grams of dried tissue
12. To the HCl solution pepsin was added in a ratio of 1:50, then stored at 20°C for 24 hours
13. Solution was placed on a platform shaker to keep the solution constantly mixing
14. 175 mL of digested solution was placed into 200 mL centrifuge tubes and centrifuged for 30 minutes at 12,500 rpms
15. After centrifuging the supernatant was collected and the pH was adjusted to 10 using NaOH and stored at 4°C for 24 hours
16. The pH was the adjusted to 7 using HCl solution
17. The solution was then washed by adding 500 mL per 2000 mL of solution
18. The solution was the placed into the 200 mL centrifuged tubes and centrifuged for 30 minutes at 12,500 rpms
19. The precipitate was collected and then rinsed with deionized water, stirred and recentrifuged 3 times
20. The precipitate was collected and suspended into a .5 M solution of acetic acid in the ratio of .121 g collagen per 1mL acetic acid solution

## APPENDIX C

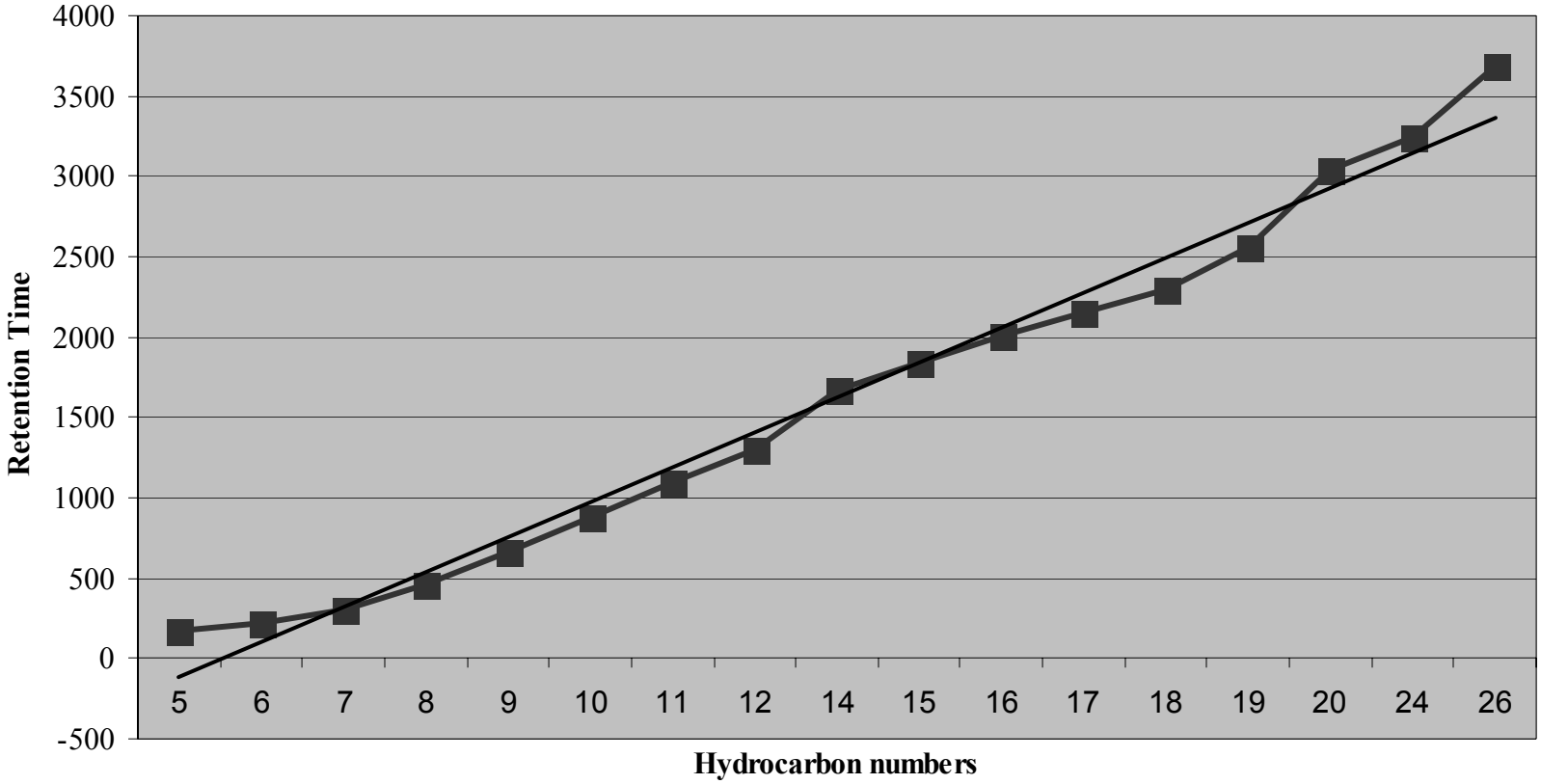


Figure 6. Kovat's Index for Identification of Compounds for Gas Chromatography.

## APPENDIX D

**Percent Identification of Compounds from Mass Spec./GC for Jungle Day 8 and Ambient Conditions Day 30**

| Compound Name | Percent Identification for Jungle Cond. | Percent Identification for Ambient Cond. |
|---|---|---|
| Acetic Acid | 90% | 90% |
| Butanal, 3 methyl | 80% | 88% |
| Hexanal | 91% | 90% |
| Tetrachloroethylene | 98% | 98% |
| Heptane, 2,2,4,6,6 pentamethyl | 83% | 94% |
| B-myrcene | 93% | 95% |
| D-Limonene | 94% | 94% |
| Nonanal | 83% | 94% |
| Hexadecane | 98% | 99% |
| Heptadecane | 97% | 97% |
| Octadecane | 99% | 99% |
| Eicosane | 99% | 99% |
| Tetracosane | 98% | 98% |
| Nonadecane | 96% | ---- |
| Docasane | ---- | 99% |
| Hexacosane | 99% | ---- |

# APPENDIX E
# GC-O BEGINNING

Rep 1. Treatment 1 (Control)

| Rt | Aroma | Level |
|---|---|---|
| 1.71 | musty | 2 |
| 1.75 | cooked | 2 |
| 1.75 | cooked | 1 |
| 1.94 | grilled steak | 2 |
| 2.13 | musty | 1 |
| 2.65 | rancid | 2 |
| 4.24 | fecal/putrid | 1 |
| 4.25 | stinky | 1 |
| 4.33 | sour | 1 |
| 4.69 | sour | 1 |
| 4.92 | medicinal | 1 |
| 5.27 | earthy | 1 |
| 5.39 | cheesy/rancid | 1 |
| 5.60 | musty/moldy | 2 |
| 6.69 | cooked meat flavor | 1 |
| 6.71 | mealy/cat food | 2 |
| 6.84 | chromium picolinate | 3 |
| 7.07 | sweet | 1 |
| 7.18 | nutty | 2.5 |
| 8.33 | phenolic/fish oils | 1 |
| 8.35 | chemical/phenolic | 2 |
| 8.40 | grassy | 2 |
| 8.43 | tart | 1 |
| 8.53 | bitter/sour | 1 |
| 9.57 | medicinal | 1 |
| 10.65 | earthy | 1 |
| 10.77 | phenolic | 1 |
| 10.80 | moldy | 1 |
| 12.04 | chinese food | 1.5 |
| 12.05 | phenolic/medicinal | 1 |
| 12.25 | medicinal | 1.5 |
| 12.27 | earthy/medicinal | 2 |
| 13.41 | medicinal | 1 |
| 15.01 | chemical | 1 |
| 16.49 | baked aroma | 1.5 |

Rep 2 Treatment 1 (Control)

| Rt | Aroma | Level |
|---|---|---|
| 1.70 | cooked | 1 |
| 1.79 | moldy | 1 |
| 2.17 | acid/sour | 1 |
| 4.34 | phenolic | 1 |
| 5.16 | phenolic | 1 |
| 5.28 | rancid/cheesy | 1 |
| 5.37 | phenolic | 1 |
| 6.19 | fruity/baked | 2 |
| 6.67 | chromium picolinate | 1.5 |
| 6.75 | chromium picolinate | 2 |
| 6.77 | baked aroma | 2 |
| 7.06 | baked/nutty | 1.5 |
| 7.17 | buttery | 1 |
| 8.29 | musty | 1 |
| 8.39 | earthy | 1.5 |
| 8.50 | earthy/mushrooms | 1 |
| 8.50 | rubbery/garbage | 1.5 |
| 10.60 | nutty/musty | 1 |
| 10.70 | medicinal | 2 |
| 10.72 | burnt cereal | 1 |
| 11.08 | baked | 1 |
| 12.12 | musty/moldy/mush | 1.5 |
| 12.22 | musty | 1 |
| 14.02 | slight burnt | 1 |
| 14.17 | rubbery/metallic | 1 |
| 14.48 | rubbery/plastic | 1 |
| 15.10 | rubbery/plastic | 1 |
| 15.54 | fruity | 1 |
| 16.11 | fruity | 1 |
| 16.28 | spicy | 1 |
| 16.30 | roasted/spicy | 1 |
| 16.42 | floral | 1 |
| 16.90 | phenolic | 1 |
| 17.99 | burnt/medicinal | 1 |
| 18.39 | rubbery/medicinal | 1 |
| 18.70 | medicinal | 1 |

Rep 3 Treatment 1 (Control)

| Rt | Aroma | Level |
|---|---|---|
| 1.24 | fatty | 1 |
| 1.59 | burnt | 1 |
| 1.69 | sour | 1 |
| 1.82 | fishy/meaty | 1 |
| 1.98 | rubber | 1 |
| 2.21 | acid/sour | 1 |
| 2.24 | stinky | 1 |
| 2.35 | coffee | 2 |
| 2.71 | cheesy/rancid | 1 |
| 2.84 | sweet | 1 |
| 2.92 | coffee | 1 |
| 3.35 | vanilla | 1 |
| 4.15 | vegetable like | 1 |
| 4.17 | musky | 1 |
| 4.40 | cheesy | 1 |
| 4.48 | floral | 1 |
| 4.87 | earthy | 1 |
| 5.12 | metallic | 1 |
| 5.35 | fatty | 2 |
| 5.43 | rancid/cheesy | 1.5 |
| 5.60 | musty | 1 |
| 5.60 | rubber | 1 |
| 5.65 | earthy | 2 |
| 5.95 | ethereal | 1 |
| 6.40 | plastic | 1 |
| 6.84 | fatty/cheesy | 1 |
| 6.85 | chronium picolinate | 1 |
| 7.05 | floral | 1 |
| 7.05 | herbaceous | 1 |
| 7.21 | nutty/baked | 1 |
| 7.74 | citrus | 1 |
| 7.80 | floral | 1 |
| 8.33 | floral/fruity | 1 |
| 8.38 | musky/rubbery | 1 |
| 8.45 | sulfurous/grassy | 1 |
| 8.57 | sulfurous/metallic | 2 |
| 8.70 | musky | 1 |
| 9.36 | moss | 1 |
| 9.68 | cooked | 1 |
| 10.60 | rubbery putrid/pungent/burnt | 1 |
| 10.78 | plastic | 1 |
| 10.83 | floral | 2 |

| | | |
|---|---|---|
| 11.04 | grassy | 1 |
| 11.05 | earthy | 1 |
| 11.50 | mossy | 1 |
| 11.55 | musky | 1 |
| 11.65 | floral | 1 |
| 12.17 | nutty | 2 |
| 12.20 | ethereal | 1 |
| 12.26 | earthy/woody | 1 |
| 12.68 | balsamic | 1 |
| 12.85 | plastic | 1 |
| 12.97 | plastic | 1 |
| 13.34 | vegetable like | 1 |
| 14.15 | baked | 1 |
| 14.65 | floral/sweet | 1 |
| 15.02 | floral | 1 |
| 15.26 | floral | 1 |
| 15.98 | musty | 1 |
| 16.30 | rubbery | 1 |
| 16.67 | celery | 1 |
| 16.80 | nutty/poultry | 1 |
| 17.40 | spicy/herbacceous | 1 |
| 17.58 | balsamic | 1 |
| 18.16 | sweet | 1 |
| 18.50 | wine-like | 1 |
| 18.52 | sweat | 1 |
| 18.98 | mossy | 1 |
| 18.92 | sweet | 1 |

Rep 1 Treatment 2

| Rt | Aroma | Level |
|---|---|---|
| 1.44 | sweet | 1 |
| 1.73 | grassy | 1 |
| 2.24 | acid | 2 |
| 2.62 | baby powder | 1 |
| 2.79 | cooked | 1.5 |
| 3.70 | chemical | 2 |
| 4.17 | balsamic | 2 |
| 5.64 | musty/dirty feet | 2 |
| 6.70 | cooked | 1 |
| 6.87 | chrmoium picolinate | 3 |
| 7.22 | nutty | 2 |
| 8.33 | grassy | 2 |
| 8.52 | sour | 1 |
| 8.58 | grassy | 1 |
| 9.49 | sweet/roasted | 1 |
| 10.07 | sweet | 1 |
| 10.20 | phenolic | 1 |
| 10.24 | sweet | 1 |
| 10.57 | earthy | 2 |
| 10.59 | cooked meat | 2 |
| 10.82 | phenolic/earthy | 2 |
| 10.98 | dry buttermilk powder | 2 |
| 11.23 | nutty | 1 |
| 12.09 | grassy/meaty | 2 |
| 12.27 | grassy | 1.5 |

Rep 2 treatment 2

| Rt | Aroma | Level |
|---|---|---|
| 1.98 | earthy | 1 |
| 2.59 | cheesy | 1 |
| 3.15 | earthy/damp | 1 |
| 4.27 | earthy | 1 |
| 4.27 | buttery | 1 |
| 4.80 | rubbery | 1 |
| 5.36 | burnt/rubbery | 1 |
| 5.48 | musty | 1 |
| 6.05 | fruity/musty | 1 |
| 6.70 | chromium picolinate | 2 |
| 6.71 | sweet | 1 |
| 6.72 | baked aroma | 1.5 |
| 6.79 | chromium picolinate | 2 |
| 6.85 | burnt | 1 |
| 7.10 | baked nutty | 1.5 |
| 7.19 | baked | 1 |
| 7.48 | mushrooms | 1 |
| 8.27 | floral/fruity | 1 |
| 8.33 | musty/medicinal | 1 |
| 8.43 | earthy | 1 |
| 8.45 | medicinal | 1 |
| 8.46 | musty/smokey | 1 |
| 9.39 | musty | 1 |
| 9.89 | sweet balsamic | 1 |
| 9.98 | grainy | 1 |
| 10.14 | musty/meaty | 1 |
| 10.26 | paper aroma | 1 |
| 10.52 | musty | 1 |
| 10.63 | earthy/mushrooms | 1 |
| 10.65 | meaty | 1.5 |
| 10.75 | chemical/medicinal | 1 |
| 11.08 | baked/roasted | 1 |
| 11.08 | meaty/medicinal | 1 |
| 11.20 | grainy | 1 |
| 11.29 | phenolic | 1 |
| 12.10 | earthy | 1 |
| 12.12 | baked | 1 |
| 12.18 | phenolic | 1 |
| 12.78 | baked | 1 |
| 13.48 | floral | 1 |
| 15.54 | floral | 3 |
| 17.86 | papery | 1 |

Rep 3 Treatment 2

| Rt | Aroma | Level |
|---|---|---|
| 0.99 | sweet | 1 |
| 1.20 | balsamic | 1 |
| 1.60 | burnt | 1 |
| 1.72 | sour | 1 |
| 1.80 | vegetable | 1 |
| 1.82 | fatty | 2 |
| 2.18 | cheesy | 1 |
| 2.28 | fatty | 1 |
| 2.62 | rubbery/musty | 1 |
| 2.65 | rancid | 1 |
| 2.76 | medicinal | 2 |
| 2.88 | sweet | 1 |
| 3.31 | burnt | 1 |
| 3.55 | musty | 1 |
| 3.78 | earthy | 1 |
| 4.09 | floral | 1 |
| 4.10 | spicy | 1 |
| 4.38 | ethereal | 1 |
| 4.35 | stinky | 1 |
| 4.79 | sweet | 1 |
| 4.90 | balsamic | 2 |
| 5.39 | rancid/musty | 1 |
| 5.48 | musty | 1 |
| 5.53 | sweet | 1 |
| 5.59 | musty | 1.5 |
| 6.19 | soapy | 2 |
| 6.27 | musty/mossy | 1 |
| 6.45 | sweet | 1 |
| 6.54 | cheesy/fatty | 3 |
| 6.69 | poultry | 1 |
| 6.79 | chromium picolinate | 2 |
| 6.82 | medicinal | 2 |
| 6.90 | spicy | 1 |
| 7.15 | fruity/sweet | 2 |
| 7.17 | nutty/baked | 1.5 |
| 7.41 | mossy/viney | 1 |
| 7.50 | hazelnut | 1 |
| 8.38 | floral | 1 |
| 8.41 | sulfurous/grassy | 1.5 |
| 8.52 | sulfurous/metallic | 1.5 |
| 8.66 | metallic | 1 |
| 9.01 | earthy/ethereal | 1 |

| | | | | | |
|---|---|---|---|---|---|
| | 19.38 | rose | 1 | 9.06 | grassy |
| | | | | 9.35 | floral |
| | | | | 9.40 | baked |
| | | | | 9.65 | fruity |
| | | | | 9.70 | earthy/ethereal |
| | | | | 10.22 | sweet/stinky |
| | | | | 10.40 | fruity |
| | | | | 10.59 | nutty |
| | | | | 10.75 | balsamic/coffee |
| | | | | 10.71 | earthy/woody |
| | | | | 11.15 | nutty/baked |
| | | | | 11.15 | sweet |
| | | | | 11.81 | fruity |
| | | | | 12.10 | nutty/sweet |
| | | | | 12.20 | balsamic |
| | | | | 12.23 | woody/earthy |
| | | | | 12.45 | mushrooms |
| | | | | 13.20 | balsamic |
| | | | | 13.35 | mossy1 |
| | | | | 13.60 | coffee |
| | | | | 14.10 | stinky |
| | | | | 14.30 | citrus |
| | | | | 16.07 | musty |
| | | | | 16.34 | floral |
| | | | | 16.98 | floral |
| | | | | 19.72 | balsamic |
| | | | | 19.96 | citrus |

Rep1. Treatment 3

| Rt | Aroma | Level |
|---|---|---|
| 1.62 | baby powder | 2 |
| 1.76 | cooked | 1 |
| 1.91 | floral/soapy | 2 |
| 2.21 | balsamic | 2 |
| 2.56 | alkaline | 1.5 |
| 2.60 | sweet/foot odor | 2 |
| 2.62 | sweet | 1 |
| 2.73 | meaty | 1 |
| 2.73 | earthy/medicinal | 1 |
| 4.39 | butyric acid | 1 |
| 4.46 | cheesy/rancid | 1 |
| 4.59 | sweet/acetaldehyde | 1 |
| 4.61 | rancid | 2 |
| 5.26 | grassy/sour | 2 |
| 5.31 | rancid | 2 |
| 5.48 | musty | 2.5 |
| 5.66 | musty/woody | 3 |
| 5.97 | cooked milk | 1 |
| 6.15 | nuts/almonds | 1 |
| 6.50 | | |
| 6.54 | grassy/sour | 2 |
| 6.67 | cooking/roasting | 3.5 |
| 6.68 | grapenuts (cereal) | 3 |
| 6.78 | tuna/meaty | 2 |
| 6.86 | chromium picolinate | 2 |
| 8.11 | sour | 2 |
| 8.17 | aldehyde/rancid | 1 |
| 8.29 | medicinal | 2 |
| 8.39 | sulfurous | 1 |
| 8.47 | earthy/medicinal | 1 |
| 8.61 | bitter | 1 |
| 9.02 | sweet | 1 |
| 9.70 | chemical smell | 1 |
| 10.56 | cooked/rancid sour | 3 |
| 10.56 | herb | 1 |
| 10.78 | nutty | 1 |
| 11.20 | floral/perfume | 1.5 |
| 11.50 | aldehyde/green/grass y | 4 |
| 12.06 | good smell | 2 |
| 12.29 | nutty/woody | 1 |
| 12.32 | grassy | 1 |
| 12.45 | phenolic smell | 2 |
| 13.45 | grassy | 1 |

Rep 2. Treatment 3

| Rt | Aroma | Level |
|---|---|---|
| 1.64 | floral | 1 |
| 2.08 | plastic | 1 |
| 2.35 | acidic/sour | 1 |
| 2.61 | baked | 1 |
| 2.69 | baked cereal | 1.5 |
| 2.72 | phenolic | 1 |
| 2.80 | herbaceous | 1 |
| 4.20 | meaty/sulfruous | 2 |
| 4.38 | cheesy | 1 |
| 4.45 | rancid (poop) | 1 |
| 4.54 | grassy (green) | 1.5 |
| 4.73 | grassy | 1 |
| 5.28 | rancid/chessy | 1 |
| 5.39 | cheesy | 1.5 |
| 5.40 | stinky feet/musty | 2 |
| 5.54 | rancid/ musty | 1.5 |
| 5.92 | baked/roasted | 1 |
| 6.12 | baked aroma | 2 |
| 6.62 | meaty | 1 |
| 6.64 | baked meat | 2 |
| 6.65 | chromium picolinate | 2 |
| 6.85 | vitamin smell | 2 |
| 7.07 | roasted/baked/nutty | 2 |
| 8.15 | sulfurous | 1 |
| 8.24 | plastic/burnt | 2 |
| 8.28 | sulfurous | 2.5 |
| 8.39 | sulfuruos | 1 |
| 8.40 | mushroooms | 1 |
| 8.65 | grassy/aroma | 1 |
| 9.75 | sweet/earthy | 1 |
| 9.89 | sweet (balsamic) | 2 |
| 10.08 | sweet | 1 |
| 10.59 | musty | 1 |
| 10.67 | burnt/plastic | 1 |
| 10.73 | musty/metallic | 2 |
| 10.92 | corn syrup | 1 |
| 11.04 | woody | 1 |
| 11.19 | sweet | 1 |
| 11.25 | grainy | 1 |
| 12.09 | medicinal | 1 |
| 12.15 | cooked/roasted | 1 |
| 12.27 | musty | 1 |
| 12.27 | medicinal | 1 |

Rep 3. Treatment 3

| Rt | Aroma | Level |
|---|---|---|
| 1.43 | cooked | 1 |
| 2.03 | cat food | 1 |
| 2.15 | sour/acidic | 1 |
| 2.35 | sour | 1 |
| 2.45 | very acetic acid | 2 |
| 2.63 | sour/citrus | 1 |
| 2.63 | stinky/putrid | 1 |
| 3.05 | cooked/ stinky | 1 |
| 4.39 | rancid | 1 |
| 4.48 | meaty/stinky | 1 |
| 4.51 | cheesy | 1.5 |
| 4.61 | grassy | 1 |
| 5.20 | fatty | 1 |
| 5.38 | earthy/sour | 1 |
| 5.45 | cheese/sour | 2 |
| 5.55 | musty | 1 |
| 5.56 | musty | 2 |
| 5.98 | baked/nutty | 1 |
| 6.10 | dry paste/bread | 2 |
| 6.71 | chromium picolinate | 2 |
| 6.80 | baked/stinky | 2 |
| 7.11 | nutty | 2 |
| 8.24 | sulfurous/onions | 1 |
| 8.33 | sulfurous/metallic | 1 |
| 8.33 | spicy/herbaceous | 1 |
| 8.41 | metallic | 1 |
| 8.64 | rancid | 1 |
| 9.98 | sweet/balsamic | 1 |
| 10.63 | earthy/woody | 1 |
| 10.76 | nutty | 2 |
| 10.80 | rubber | 1 |
| 10.97 | sweet | 1 |
| 11.11 | baked aroma | 1 |
| 11.22 | balsamic/caramel | 2 |
| 12.20 | nutty | 2 |
| 12.23 | sweet | 1 |
| 13.11 | woody | 1 |
| 13.32 | soapy/fresh | 1 |
| 13.38 | herbaceous | 1 |
| 15.07 | musty | 1 |
| 15.20 | fruity/sweet | 1 |
| 15.50 | sweet | 1 |
| 16.30 | musty | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 15.15 | earthy | 1.5 | 12.55 | roasted/baked/nutty | 1 |
| 15.72 | chemically | 1 | 13.27 | roasted/baked/nutty | 1 |
| 16.16 | sweet | 1 | 13.50 | musty | 1 |
| 17.01 | medicinal/chemical | 1 | 13.85 | medicinal/phenolic | 1 |
| 17.99 | phenolic smell | 1 | 14.39 | medicinal | 1.5 |
| | | | 15.22 | baked/minty | 1 |
| | | | 16.49 | floral | 1 |
| | | | 16.95 | medicinal | 1 |
| | | | 17.13 | fruity | 1 |
| | | | 17.45 | medicinal | 1 |
| | | | 18.76 | musty | 1 |

| | | |
|---|---|---|
| 16.32 | floral | 1 |
| 16.63 | baked bread | 1 |
| 16.68 | moldy | 1 |
| 17.83 | sour/catfood | 1.5 |
| 18.14 | baked bread | 1 |
| 18.22 | spicy/poultry | 1 |
| 19.10 | floral | 1 |
| 19.68 | stinky/vegetable | 1 |

Rep 1 Treatment 4

| Rt | Aroma | Level |
|---|---|---|
| 1.35 | phenolic | 1.5 |
| 1.90 | baby powder | 2 |
| 2.16 | balsamic | 1 |
| 2.23 | acid | 2 |
| 2.49 | acetic acid | 3 |
| 2.52 | sour/acetic acid | 1 |
| 2.67 | cardboary | 1 |
| 2.71 | mushrooms/pungent | 2 |
| 4.37 | rancid/peanutty | 4 |
| 4.53 | cheesy | 1 |
| 4.64 | bitter/grassy | 1 |
| 4.72 | grassy | 1 |
| 5.20 | phenolic | 1 |
| 5.30 | sour/grassy | 1 |
| 5.32 | rancid/cheesy | 2.5 |
| 5.46 | rancid/cheesy | 1 |
| 5.66 | musty/chessy | 1.5 |
| 6.04 | sweet | 1 |
| 6.17 | phenolic | 2 |
| 6.57 | unknown | 2 |
| 6.66 | grapenuts/cereal | 3 |
| 6.70 | roasted | 3 |
| 6.85 | chromium picolinate | 2 |
| 7.15 | phenolic | 1 |
| 7.21 | nutty | 1.5 |
| 8.16 | bad/burnt meat | 3 |
| 8.29 | bad;pungent | 3 |
| 8.39 | mushrooms/earthy | 2 |
| 8.39 | sulfur/ammonina | 2 |
| 8.44 | musty | 1 |
| 8.57 | tart/musty | 1 |
| 9.91 | nuts | 2 |
| 10.02 | sweet/powder aroma | 1 |
| 10.07 | sweet/baked | 1 |
| 10.40 | bad;pungent | 3 |
| 10.78 | herby/woody | 1.5 |
| 11.07 | phenolic | 1 |
| 11.19 | nutty | 1 |
| 12.05 | phenolic | 2 |
| 12.22 | woody/medicinal | 1 |
| 12.42 | phenolic | 1 |
| 13.99 | sweet/powdery | 1 |
| 14.23 | slight floral | 1 |
| 14.62 | strong floral | 2.5 |

Rep 2 Treatment 4

| Rt | Aroma | Level |
|---|---|---|
| 0.72 | floral | 1 |
| 2.12 | acidic/sour | 1.5 |
| 2.42 | acetic acid | 1 |
| 2.65 | roasted/baked aroma | 1 |
| 2.67 | musty | 1 |
| 2.74 | woody/earthy | 1 |
| 2.75 | mushrooms | 1 |
| 3.31 | plastic | 1 |
| 4.40 | cheesy | 1 |
| 4.44 | cheesy | 1 |
| 4.51 | cheesy | 2 |
| 4.75 | grassy | 1 |
| 5.32 | cheesy/rancid/musty | 1 |
| 5.35 | rancid | 2 |
| 5.43 | musty | 2 |
| 5.53 | musty | 2.5 |
| 6.62 | metallic/sulfurous | 1 |
| 6.68 | chromium picolinate | 1.5 |
| 6.77 | baked cereal | 2.5 |
| 6.79 | vitamins | 2 |
| 7.04 | phenolic | 1 |
| 7.05 | baked/roasted | 1.5 |
| 7.22 | grainy/sweet | 1 |
| 8.17 | sulfurous | 1 |
| 8.20 | stinky/rancid | 2 |
| 8.30 | sulfurous | 2 |
| 8.32 | musty | 3 |
| 8.42 | musty | 2 |
| 8.42 | mushrooms | 1.5 |
| 8.51 | burnt | 1 |
| 9.65 | lemon | 1 |
| 9.87 | sweet/balsamic | 2 |
| 10.03 | sweet | 1.5 |
| 10.56 | roasted/baked aroma | 1.5 |
| 10.61 | nutty/baked | 2 |
| 10.80 | musty | 1 |
| 11.02 | sweet/baked | 1 |
| 11.24 | fritos | 1 |
| 12.08 | woody/earthy | 1 |
| 12.12 | roasted | 1.5 |
| 12.24 | earthy | 1 |
| 12.62 | fruity | 1 |
| 12.99 | fruity/green | 1 |
| 14.14 | musty | 1 |

Rep 3 Treatment 4

| Rt | Aroma | Level |
|---|---|---|
| 1.70 | cooked | 1 |
| 2.03 | meaty/fishy | 1 |
| 2.16 | sour/acidic | 1.5 |
| 2.32 | sour/acidic | 1 |
| 2.43 | sour | 1 |
| 2.55 | sour | 1 |
| 2.62 | rancid | 1 |
| 2.80 | butter | 1 |
| 3.12 | fresh/soapy | 1 |
| 3.32 | musky/stinky | 1 |
| 4.42 | cheesy | 1 |
| 4.44 | cheesy/sour | 1 |
| 4.54 | baked | 1 |
| 4.61 | grassy/sweet | 1 |
| 4.88 | fatty | 1 |
| 5.05 | floral/viney | 1 |
| 5.16 | rubber | 1 |
| 5.45 | fatty/cheesy/sour | 1 |
| 5.55 | musty | 1 |
| 6.10 | musty/moldy | 1 |
| 6.71 | chromium picolinate | 2 |
| 6.80 | meaty/grainy/catfood | 2 |
| 7.09 | earthy/ethereal | 1 |
| 7.10 | nutty/baked | 1 |
| 7.56 | balsamic | 1 |
| 8.33 | earthy/grassy | 1 |
| 8.44 | earthy | 1 |
| 8.48 | ethereal | 1 |
| 8.49 | peanutty | 1 |
| 8.72 | fatty/vegetable | 1 |
| 9.75 | earthy | 1 |
| 9.93 | sweet | 1 |
| 10.19 | metallic | 1 |
| 10.38 | sweet | 1 |
| 10.66 | earthy/woody/musty | 1 |
| 10.79 | nutty/floral | 1 |
| 10.94 | coffee/caramel | 1 |
| 11.09 | baked | 1 |
| 11.19 | nutty | 1 |
| 11.19 | creamy | 1 |
| 12.15 | woody/earthy | 1 |
| 12.18 | nutty/sweet | 2 |
| 12.30 | ethereal | 1 |
| 13.30 | earthy/floral | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 15.27 bitter/sour | 1 | 14.54 baked/medicinal | 1 | 14.21 mossy | 1 |
| 15.57 sweet | 1 | 14.97 baked/rancid | 1 | 15.30 earthy | 1 |
| 15.87 meaty/sulfury | 1 | 15.56 rubbery | 1 | 15.45 floral | 1 |
| 17.87 earthy/acidic | 1 | 18.04 musty | 1 | 15.75 cereal | 1 |
| 19.35 unknown | 1 | | | 16.39 poultry/cooked | 1 |
| | | | | 16.69 spicy/herbaccous | 2 |
| | | | | 16.98 cooked/pasta | 1 |
| | | | | 17.35 poultry/cooked | 1 |
| | | | | 18.05 ethereal | 1 |
| | | | | 18.28 sweet | 1 |
| | | | | 18.49 onion/grassy | 1 |
| | | | | 18.95 citrus/vegetable | 1 |

Rep 1. Treatment 5

| Rt | Aroma | Level |
|---|---|---|
| 1.83 | earthy | 1 |
| 1.88 | meaty | 1 |
| 2.10 | acetic acid/feet | 2 |
| 2.20 | rancid | 2 |
| 2.37 | sweet | 1 |
| 2.57 | baked goods | 1 |
| 4.36 | stinky (sulfur) | 4 |
| 4.36 | floral | 2 |
| 4.39 | cheesy | 2 |
| 4.74 | floral/grassy | 1 |
| 5.27 | baked smell | 1 |
| 5.28 | urine | 2 |
| 5.48 | rancid | 2.5 |
| 5.65 | musty | 2 |
| 5.87 | floral | 1 |
| 6.01 | floral | 1 |
| 6.62 | floral/baked grainy | 2 |
| 6.65 | grapenuts cereal | 3 |
| 6.83 | chromium picolinate | 2 |
| 7.05 | cooked milk | 2 |
| 7.21 | nutty | 2 |
| 7.46 | grassy | 1 |
| 8.22 | rubbery/plastic | 2 |
| 8.37 | grassy | 3.5 |
| 8.39 | cooked | 2 |
| 8.44 | earthy/woody | 2 |
| 8.54 | sulfurous | 2 |
| 9.10 | earthy | 1 |
| 9.28 | nutty/roasted | 1 |
| 9.92 | acetaldehyde | 1 |
| 10.28 | floral | 1 |
| 10.47 | floral/soapy | 2 |
| 10.65 | earthy/musty | 1 |
| 10.79 | nutty/earthy | 1.5 |
| 10.92 | phenolic | 1 |
| 11.02 | rancid | 1 |
| 11.18 | nutty | 1 |
| 11.38 | floral | 2 |
| 11.48 | rancid/sour | 1 |
| 12.11 | stale bread | 1 |
| 12.24 | musty | 1 |
| 12.58 | chemically/phenolic | 2 |
| 15.64 | floral | 3 |
| 16.34 | sharp/organic | 1 |

Rep 2 Treatment 5

| Rt | Aroma | Level |
|---|---|---|
| 1.04 | musty | 1 |
| 2.07 | musty | 1 |
| 2.21 | rancid | 1 |
| 2.46 | acidic/sour | 1 |
| 2.64 | baked aroma | 1.5 |
| 2.70 | earthy | 1 |
| 2.74 | burned coffee | 1 |
| 4.47 | cheesy | 1 |
| 4.52 | rancid | 1 |
| 4.73 | grassy | 1 |
| 5.42 | rancid/cheesy | 1 |
| 5.43 | mushrooms | 1 |
| 5.64 | musty | 1 |
| 6.12 | baked aroma | 1 |
| 6.66 | burnt/cooked meat | 2 |
| 6.74 | meaty | 1 |
| 6.79 | grainy | 2 |
| 6.86 | chromium picolinate | 1 |
| 7.27 | baked/nutty | 1 |
| 8.30 | herbacceous | 1 |
| 8.36 | sulfurous/onions | 1 |
| 8.42 | herbacceous/med. | 2 |
| 8.42 | sweet | 1 |
| 8.45 | medicincal | 1 |
| 8.51 | musty | 1 |
| 8.53 | sulfurous | 2 |
| 10.10 | sweet | 1.5 |
| 10.39 | musty | 1 |
| 10.75 | medicinal | 1.5 |
| 10.82 | earthy/woody | 1 |
| 10.93 | phenolic | 2 |
| 11.18 | sweet/nutty | 1 |
| 11.27 | baked cereal | 1 |
| 12.21 | roasted/baked | 1 |
| 12.29 | musty | 1 |
| 12.29 | earthy | 1 |
| 16.48 | baked | 1 |
| 17.35 | phenolic | 1 |

Rep 3 Treatment 5

| Rt | Aroma | Level |
|---|---|---|
| 0.97 | floral | 1 |
| 1.20 | bread | 1 |
| 1.88 | floral | 1 |
| 1.98 | grainy/meaty | 1 |
| 2.19 | sour/acidic | 1.5 |
| 2.37 | metallic | 1 |
| 2.54 | stinky/sour | 1 |
| 2.66 | rancid/cheesy | 1.5 |
| 2.80 | pungent/gassy | 1 |
| 3.59 | musty | 1 |
| 4.28 | ethereal | 1 |
| 4.47 | fatty/cheesy | 2 |
| 4.49 | cheesy | 1 |
| 4.66 | grassy | 1 |
| 4.78 | grassy/herbacceous | 1 |
| 5.12 | cereal | 1 |
| 5.43 | fatty/cheesy | 2 |
| 5.49 | wet dog | 1 |
| 5.61 | musty | 1 |
| 5.63 | musty/moldy | 1 |
| 6.05 | baked/roasted | 1 |
| 6.68 | poultry | 1 |
| 6.78 | grainy/meaty | 2 |
| 6.79 | chromium picolinate | 1.5 |
| 7.17 | nutty | 1.5 |
| 7.20 | balsamic | 2 |
| 7.30 | woody | 1 |
| 7.41 | mossy | 1 |
| 8.25 | spicy | 1 |
| 8.29 | phenolic | 1 |
| 8.43 | vegetable | 1 |
| 8.44 | sulfurous/grassy | 1 |
| 8.49 | sulfurous/metallic | 2 |
| 8.65 | rubbery | 1 |
| 9.36 | baked/roasted | 1 |
| 9.44 | nutty | 1 |
| 10.06 | sweet/floral | 1 |
| 10.61 | earthy | 1 |
| 10.72 | earthy/woody | 1.5 |
| 10.76 | nutty/sweet | 2 |
| 10.88 | woody | 1 |
| 10.92 | burnt fat | 1 |
| 11.09 | coffee | 1 |
| 11.16 | nutty | 1 |

| | |
|---|---|
| 16.72 swet/organic aroma | 1 |
| 16.96 fishy/grainy | 1 |
| 17.94 floral | 1 |
| 18.09 medicinal | 1 |
| 18.70 meaty | 2 |

| | |
|---|---|
| 11.17 nutty | 1 |
| 11.78 rancid/cheesy | 1 |
| 12.20 nutty/peanutbutter | 2 |
| 12.22 floral | 1 |
| 12.40 floral | |
| 13.85 stinky/mossy | 1 |
| 13.96 sweet/floral | 1 |
| 17.64 mossy | 1 |
| 18.68 mosey/viney | 1 |
| 19.78 vanilla | 1 |

Rep 1 Treatment 6

| Rt | Aroma | Level |
|---|---|---|
| 1.07 | floral | 2 |
| 1.86 | meaty | 1 |
| 2.16 | sour/balsamic | 2 |
| 2.20 | floral | 1 |
| 2.25 | cheesy | 2 |
| 2.36 | acid | 2 |
| 2.60 | earthy | 1 |
| 2.63 | roasted | 1 |
| 2.68 | rancid | 2 |
| 3.20 | baked | 1 |
| 4.29 | stinky/rotten | 3 |
| 4.47 | cheesy/rancid | 1 |
| 4.55 | ammonia | 1 |
| 4.69 | grassy/green | 1 |
| 4.69 | floral | 1 |
| 5.01 | floral | 1 |
| 5.23 | bad perfume | 1 |
| 5.30 | rancid | 2 |
| 5.42 | cheesy/rancid | 1.5 |
| 5.64 | musty | 1.5 |
| 5.97 | sour/stinky | 1 |
| 6.61 | french fries | 3 |
| 6.70 | grapenuts (cereal) | 3 |
| 6.80 | chromium picolinate | 2 |
| 7.05 | phenolic | 1 |
| 7.07 | butter/sweet | 1 |
| 7.18 | nutty | 1.5 |
| 8.25 | plasticy | 2 |
| 8.30 | meaty | 1 |
| 8.32 | chemical/medicinal | 2 |
| 8.37 | wheat/grassy | 1.5 |
| 8.40 | earthy | 1 |
| 8.51 | sulfury | 1 |
| 10.24 | fart | 1 |
| 10.53 | smokey/burnt | 1 |
| 10.74 | roasted/nutty | 1.5 |
| 11.03 | grassy | 2 |
| 11.22 | floral | 1 |
| 11.40 | floral | 2 |
| 12.04 | floral/phenolic | 1 |
| 12.20 | earthy/woody | 1 |
| 13.66 | floral | 1 |
| 15.11 | grainy | 1 |
| 15.68 | floral | 1 |

Rep 2 Treatment 6

| Rt | Aroma | Level |
|---|---|---|
| 1.68 | cooked | 1 |
| 2.16 | acid/sour | 1 |
| 2.64 | ethereal/stinky | 1 |
| 2.69 | roasted | 1 |
| 3.91 | sweet | 1 |
| 4.20 | floral | 1 |
| 4.40 | burnt | 1 |
| 4.47 | cheesy | 1 |
| 4.61 | grassy | 1 |
| 4.74 | bell pepper | 1 |
| 5.27 | sweet | 1 |
| 5.33 | rancid | 1 |
| 5.41 | rancid | 1 |
| 5.54 | musty | 1 |
| 5.90 | phenolic | 1 |
| 6.66 | meaty | 1 |
| 6.70 | chromium picolinate | 1 |
| 6.82 | bad/baked | 1 |
| 6.83 | chromium picolinate | 2 |
| 6.88 | baked/roasted | 2.5 |
| 7.10 | nutty/roasted | 1 |
| 7.18 | nutty | 1 |
| 7.86 | musty/rancid | 1 |
| 8.33 | rubbery/plastic | 2 |
| 8.34 | sulfurous/metallic | 1 |
| 8.39 | mushrooms | 1 |
| 8.43 | sulfurous | 2 |
| 10.04 | sweet | 1 |
| 10.65 | musty/medicinal | 1 |
| 10.74 | musty | 1 |
| 10.74 | nutty/baked | 1 |
| 10.94 | nutty/roasted | 1 |
| 11.10 | nutty/roasted | 1.5 |
| 12.11 | metallic/ammonia | 1 |
| 12.23 | baked | 1 |
| 12.25 | grassy | 1 |
| 12.34 | phenolic | 1 |
| 19.92 | rubbery/plastic | 1 |

Rep 3 Treatment 6

| Rt | Aroma | Level |
|---|---|---|
| 2.02 | rancid | 1 |
| 2.17 | rancid/cheesy | 1 |
| 2.25 | spicy | 1 |
| 2.31 | acetic acid/sour | 2 |
| 2.50 | floral | 1 |
| 2.72 | rancid | 2 |
| 3.18 | mossy | 1 |
| 4.39 | cheesy/rancid | 2 |
| 4.70 | grassy/fruity | 2 |
| 5.25 | creamy | 1 |
| 5.46 | pungent/rancid | 1 |
| 5.65 | musty | 1.5 |
| 6.12 | baked | 1 |
| 6.41 | plastic | 1 |
| 6.55 | friuty | 1 |
| 6.75 | boiled poultry | 1 |
| 6.87 | chromium picolinate | 2 |
| 7.22 | nutty | 1.5 |
| 7.60 | vegetable/fatty | 1 |
| 7.64 | sweet | 1 |
| 7.70 | fruity | 1 |
| 8.47 | metallic | 2 |
| 8.60 | sulfuruos/metallic | 2 |
| 8.64 | rubber | 1 |
| 10.81 | earthy/woody | 2 |
| 10.95 | viney | 1 |
| 11.15 | fruity | 1 |
| 11.24 | baked | 1 |
| 11.89 | roasted | 1 |
| 12.28 | earthy/woody | 2 |
| 12.48 | floral | 1 |
| 14.75 | baked bread | 1 |
| 15.20 | fatty | 1 |
| 16.47 | fruity | 1 |
| 18.58 | baked bread | 1 |
| 19.70 | roasted | 1 |

| | | |
|---|---|---|
| 15.99 | phenolic | 1 |
| 16.74 | phenolic | 1 |
| 17.75 | floral | 1 |
| 18.21 | soapy/fresh | 1 |
| 19.39 | phenolic | 1 |

# APPENDIX F
# GC-O JUNGLE CONDITIONS

| Rep 1 Treatment 1 Jungle | | | Rep 2 Treatment 1 Jungle | | | Rep 3 Treatment 1 jungle | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 1.59 | meaty/cheesy | 1 | 1.74 | Fruity | 1 | 1.62 | medicinal | 1 |
| 1.76 | meaty | 1 | 1.76 | Sour | 2 | 1.76 | cat urine | 1 |
| 1.96 | earthy | 1 | 1.98 | sour acidic | 1 | 1.77 | woody/musty | 1 |
| 2.11 | cheesy | 1 | 2.09 | stinky/pungent | 1.5 | 1.94 | acid/sour | 1 |
| 2.29 | rancid | 1 | 2.12 | Citrus | 1 | 2.03 | woody/musty | 1 |
| 2.57 | rancid | 1 | 2.19 | cheesy/rancid | 2 | 2.06 | nutty/roasted | 1 |
| 2.72 | roasted peanuts | 2 | 2.33 | Sour | 1 | 2.42 | nutty | 1 |
| 2.73 | roasted | 1 | 2.33 | Citrus | 1 | 2.67 | baked cereal | 2 |
| 4.31 | cheesy | 1.5 | 2.34 | Meaty | 1 | 2.78 | vegetabke | 1 |
| 4.38 | cheesy | 2 | 2.57 | sour/acid | 1 | 3.16 | floral | 1 |
| 4.58 | grassy | 1 | 2.70 | rancid/cheesy | 3 | 3.51 | floral | 1 |
| 4.98 | plastic | 1 | 2.74 | Earthy | 1 | 4.32 | cheesy/rancid | 1.5 |
| 5.31 | rancid | 1 | 2.80 | Nutty | 2 | 4.35 | cheesy/rancid | 4 |
| 5.43 | musty | 2 | 3.04 | Citrus | 1 | 4.50 | cheesy/rancid | 1.5 |
| 5.45 | cheesy | 1 | 3.34 | Earthy | 1 | 5.27 | alcohol | 2 |
| 5.49 | moldy | 2 | 3.85 | Floral | 1 | 5.30 | baked | 1.5 |
| 5.97 | roasted | 1 | 3.97 | Sulfurous | 1 | 5.40 | rancid/old shoes | 1.5 |
| 6.14 | earthy | 1 | 4.33 | Musty | 1 | 6.05 | nutty | 3 |
| 6.60 | meaty/fishy | 1 | 4.45 | Cheesy | 1 | 6.10 | meaty | 1 |
| 6.68 | chromium picolinate | 1 | 4.47 | Vegetable | 1 | 6.66 | vitamins | 2 |
| 6.78 | burned | 2.5 | 4.52 | Rancid | 1 | 6.74 | meaty | 2 |
| 6.80 | vitamins | 2 | 4.57 | Rancid | 1.5 | 6.77 | potato chips | 4 |
| 6.89 | baked meat | 2.5 | 4.63 | Ethereal | 3 | 6.80 | phenolic | 1 |
| 7.07 | coffee/baked | 1 | 4.70 | Grassy | 1 | 6.87 | nutty | 2 |
| 7.22 | fritos | 1.5 | 4.97 | Musty | 1 | 6.98 | fritos | 1.5 |
| 7.68 | phenolic | 1 | 5.29 | Earthy | 1 | 7.15 | roasted | 2 |
| 8.12 | phenolic | 1 | 5.41 | Musty | 2 | 7.09 | creamy | 1 |
| 8.21 | sulfurous | 1 | 5.42 | Musty | 1 | 7.42 | fruity | 1 |
| 8.31 | grassy | 1 | 5.55 | Fatty | 1 | 7.45 | mushrooms | 1 |
| 8.42 | metallic/ammonia | 2 | 5.62 | musty/moldy | 2.5 | 8.32 | new shoes/plastic | 1.5 |
| 8.55 | grassy | 1 | 6.00 | Musty | 1 | 8.42 | new shoes/plastic | 1.5 |
| 9.40 | nutty | 1 | 6.08 | baked/nutty | 1 | 8.45 | roasted | 1 |
| 9.66 | plastic | 1 | 6.23 | Grassy | 1 | 8.49 | cabbage | 1 |
| 9.94 | sweet | 1 | 6.31 | ethereal/mushrooms | 1 | 8.60 | baked | 1 |
| 10.02 | sweet | 1 | 6.72 | boiled poultry | 2 | 9.93 | medicinal | 1 |
| 10.29 | phenolic | 2 | 6.80 | Baked | 1 | 10.16 | feed/grassy | 1 |
| 10.52 | grassy | 1 | 6.80 | Chromium picolinate | 3 | 10.52 | earthy | 1 |
| 10.65 | sulfurous | 1 | 6.96 | catfood/grainy/meaty | 3 | 10.62 | burnt | 2 |
| 10.79 | woody | 1 | 7.18 | baked/nutty | 2 | 10.81 | roasted/nutty | 1 |

| | |
|---|---|
| 10.84 roasted | 1 |
| 10.86 earthy | 1 |
| 10.94 sweet | 1 |
| 11.12 rubbery | 1 |
| 11.20 earthy/ethereal | 1 |
| 11.41 phenolic | 1 |
| 12.25 woody | 1 |
| 12.26 burnt/roasted | 1 |
| 12.29 balsamic/sweet | 1 |
| 12.44 cheesy/rancid | 1 |
| 12.71 creamy | 1 |
| 15.26 phenolic | 1 |
| 15.40 fruity | 1 |
| 15.82 phenolic | 1 |
| 15.94 herbaceous | 1 |

| | |
|---|---|
| 7.21 Spicy | 1 |
| 7.40 Baked | 2 |
| 8.21 Woody | 2 |
| 8.34 Sulfurous | 1.5 |
| 8.44 Sulfurous/metallic | 2 |
| 8.57 Metallic | 3 |
| 8.61 medicinal | 1 |
| 8.64 Phenolic | 2 |
| 8.92 Phenolic | 2 |
| 8.93 Woody | 1 |
| 8.99 Earthy | 3 |
| 9.42 Baked | 1 |
| 9.50 Musty | 1 |
| 10.09 Earthy | 1 |
| 10.22 Nutty | 2 |
| 10.52 vegetable | 1 |
| 10.64 Earthy | 1 |
| 10.64 fruity/floral | 2 |
| 10.76 woody | 2.5 |
| 10.77 Fatty | 3 |
| 10.95 fatty/nutty | 4 |
| 11.05 Sweet/caramel | 2.5 |
| 11.12 Baked | 1 |
| 11.35 Sweet | 2.5 |
| 11.34 Fruity | 1 |
| 11.58 Fruity | 1.5 |
| 12.07 plastic | 1.5 |
| 12.30 Spicy | 2 |
| 12.36 grassy/nutty | 4 |
| 12.42 Earthy/woody | 3 |
| 12.69 fresh/soapy | 1.5 |
| 12.82 Baked | 1 |
| 13.34 woody | 1 |
| 14.09 plastic | 1 |
| 14.78 phenolic | 1 |
| 15.04 woody | 1 |
| 15.05 unknown | 1 |
| 15.22 fruity/grapes | 1 |
| 15.39 Minty | 1 |
| 15.40 rubbery | 1 |
| 15.80 Spicy | 1 |
| 16.16 Fruity | 1 |
| 17.90 woody | 1 |
| 19.10 Fruity | 1 |

| | |
|---|---|
| 10.96 phenolic | 1.5 |
| 11.78 burned | 1 |
| 12.12 baked/roasted | 1 |
| 12.18 burned | 1 |
| 12.20 rooty | 1 |
| 12.22 roasted1 | 1 |
| 12.40 blossom | 1 |
| 13.49 musty | 1 |
| 14.15 sweet | 1 |
| 14.26 clothes dryer | 1 |
| 14.84 sweet/floral | 1 |
| 15.05 medicinal | 1 |
| 16.00 medicinal | 2 |
| 16.40 stale | 3 |
| 17.08 plastic | 1 |
| 18.08 burnt | 1 |
| 18.30 soured | 1 |
| 18.61 phenolic | 1 |
| 18.97 roasted | 1 |
| 19.90 moss | 2 |

| Rep 1 Treatment 2 Jungle | | | Rep 2 Treatment 2 Jungle | | | Rep 3 Treatment 2 Jungle | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 1.70 | meaty | 1 | 1.35 | vegetable/earthy | 1 | 1.61 | medicinal | 1 |
| 1.68 | roasted | 1 | 1.42 | Cereal | 1 | 1.73 | cheesy | 1 |
| 2.17 | sour/cheesy | 1 | 1.78 | rotten/fatty | 1.5 | 1.76 | woody/moldy | 2 |
| 2.64 | rancid | 1 | 1.78 | Musty | 1 | 2.09 | roasted | 1 |
| 2.68 | roasted | 2 | 1.80 | Fatty | 1 | 2.17 | nutty | 3 |
| 2.70 | roasted | 1 | 1.85 | Musty | 3 | 2.23 | roasted | 1 |
| 2.74 | moldy/musty | 1 | 2.07 | nutty/baked | 1 | 2.38 | musty | 1 |
| 2.87 | roasted | 1 | 2.08 | Nutty | 2 | 2.60 | feed/nutty | 1.5 |
| 3.23 | floral | 1 | 2.21 | sour/acetic acid | 2 | 2.60 | baked potato | 2 |
| 4.09 | plastic/rubbery | 1 | 2.27 | Waxy | 1 | 2.69 | roasted | 2 |
| 4.37 | rancid/cheesy | 1 | 2.70 | rancid/pungent | 3 | 3.14 | metallic | 2 |
| 4.38 | cheesy | 1 | 2.75 | Coffee | 1 | 3.86 | sweet | 1 |
| 4.44 | cheesy | 1 | 2.80 | vegetable/fatty | 2 | 3.90 | grape | 1 |
| 4.63 | grassy | 1 | 3.05 | Buttery/fatty | 1 | 4.27 | cheesy | 1 |
| 5.34 | cheesy | 1 | 3.23 | Stinky | 1 | 4.30 | cheesy | 2 |
| 5.40 | musty | 2 | 3.35 | Earthy | 1 | 4.36 | rancid | 1 |
| 5.43 | rancid/cheesy | 1 | 3.89 | Earthy | 1 | 4.46 | cheesy | 1 |
| 5.53 | musty | 1.5 | 4.17 | ethereal/mossy | 1 | 4.56 | rancid | 1 |
| 6.00 | roasted | 1 | 4.42 | Cheesy/rancid | 2 | 4.61 | grassy | 2 |
| 6.65 | fishy | 1 | 4.44 | fruity/floral | 1 | 4.65 | grassy | 2 |
| 6.72 | chromium picolinate | 1.5 | 4.59 | cereal/fatty | 1 | 4.76 | grassy | 2 |
| 6.72 | bad/pungent | 2 | 5.16 | Musty | 1 | 5.39 | sour | 1 |
| 6.83 | vitamins | 2 | 5.16 | Soapy | 1 | 5.48 | cheesy | 1 |
| 6.88 | burned/roasted | 2 | 5.33 | fatty/minty | 2 | 5.54 | musty | 1.5 |
| 7.09 | coffee/roasted | 1.5 | 5.40 | wet dog/sour | 1 | 6.66 | roasted | 2.5 |
| 7.22 | fritos | 1.5 | 5.45 | Putrid | 3 | 6.77 | vitamins | 1.5 |
| 8.10 | phenolic | 1 | 5.62 | Musty | 1 | 6.77 | potato chip | 2 |
| 8.34 | sulfurous | 1 | 5.67 | Earthy/ethereal | 2 | 6.80 | phenolic | 1 |
| 8.43 | cardboardy | 2 | 5.69 | phenolic | 3 | 6.94 | roasted/baked | 2 |
| 8.47 | ammonia/sulfurous | 1.5 | 5.95 | wine-like | 2 | 7.11 | fritos | 1.5 |
| 8.55 | plastic | 1 | 6.22 | Soapy | 1 | 7.15 | roasted | 2 |
| 8.88 | lemon/citrus | 1.5 | 6.23 | Baked | 1 | 7.56 | fruity | 2 |
| 9.97 | sweet | 1 | 6.55 | Fruity | 3 | 7.60 | plastic | 1 |
| 10.56 | earthy | 1 | 6.64 | Soapy | 1 | 8.33 | mushrooms | 1.5 |
| 10.64 | woody/earthy | 1.5 | 6.80 | chromium picolinate | 3 | 8.42 | fresh peas | 2 |
| 10.73 | burned | 1.5 | 6.96 | catfood aroma | 2 | 8.44 | new shoes/plastic | 2 |
| 10.96 | cooked/caramel | 1 | 7.23 | nutty/baked | 2 | 8.50 | plastic | 1 |
| 11.04 | sweet | 1 | 7.32 | Nutty | 2 | 8.51 | plasticy | 2 |
| 11.09 | roasted/nutty | 1 | 7.30 | balsamic/sweet | 2 | 9.73 | creamy | 1 |
| 11.15 | musty | 1 | 7.92 | herbaceous | 1 | 10.50 | musky | 2 |
| 11.24 | sweet | 1 | 8.26 | Earthy | 1 | 10.55 | woody/earthy | 1 |

| | |
|---|---|
| 11.29 fritos | 1 |
| 11.32 sweet | 1 |
| 12.21 burned | 1 |
| 12.32 medicinal | 1 |
| 13.23 phenolic | 1 |
| 13.74 phenolic | 1 |
| 16.13 phenolic | 1 |
| 16.38 floral | 1 |
| 16.70 floral | 1 |
| 17.39 floral | 1 |
| 19.40 phenolic | 1 |

| | |
|---|---|
| 8.44 fruity/berry/sweet | 1 |
| 8.47 Earthy | 2 |
| 8.50 phenolic | 2 |
| 8.56 sulfurous | 2 |
| 8.60 Floral | 1 |
| 8.70 Plastic | 1 |
| 8.92 Woody | 1 |
| 9.35 burnt/plastic | 3 |
| 9.42 butterscotch | 1 |
| 9.56 musty/earthy | 1 |
| 10.06 Earthy | 1 |
| 10.12 Floral | 1 |
| 10.58 baked/meaty | 2 |
| 10.79 earthy/woody | 2 |
| 10.82 Baked | 2 |
| 10.82 coffee/spicy | 2 |
| 10.90 Nutty | 4 |
| 10.95 earthy/nutty | 1 |
| 11.07 sweet/caramel | 3 |
| 11.07 Sweet | 3 |
| 11.24 Baked | 1 |
| 11.33 nutty/floral | 2 |
| 11.59 Nutty | 1 |
| 11.86 Sweet | 1 |
| 12.11 Sour | 1 |
| 12.26 Woody/ethereal | 1.5 |
| 12.32 Earthy | 1 |
| 12.34 viney/nutty | 2 |
| 12.48 fresh/soapy | 1 |
| 12.51 moldy/musty | 1 |
| 13.87 ethereal | 1 |
| 14.65 Musty | 1 |
| 15.22 Fruity | 1 |
| 15.49 Floral | 1 |
| 15.60 Nutty | 1 |
| 16.42 Fruity | 1.5 |
| 16.50 Floral | 1 |
| 16.52 Floral | 1 |
| 16.73 Meaty | 1 |
| 17.22 baked/potato chip | 1 |
| 17.65 Roasted/fatty | 2 |
| 18.02 stinky/fatty | 1 |
| 18.17 meaty/musty | 1 |
| 18.46 vegetable/cheesy | 2 |
| 18.80 Meaty | 1 |
| 19.18 raw potato | 1 |

| | |
|---|---|
| 10.66 earthy | 1 |
| 10.75 old | 2 |
| 10.83 baked | 1 |
| 11.02 sweet | 1 |
| 11.17 cooked | 1 |
| 11.17 feed/cereal | 1 |
| 11.62 floral | 1 |
| 12.14 sweet/feed | 1 |
| 12.19 vegetable | 2 |
| 12.33 plastic | 1 |
| 12.29 meaty/baked | 1 |
| 13.30 roasted | 2 |
| 13.41 medicinal | 1 |
| 14.59 green | 1 |
| floral/fruity/gr | |
| 15.15 ape | 1 |
| 15.36 grape | 1 |
| 17.59 plastic | 1 |
| 18.01 moldy | 1 |
| 18.08 burnt | 1 |
| 19.85 phenolic | 1 |

| Rep 1 Treatment 3 | | |
|---|---|---|
| Rt | Aroma | Level |
| 1.92 | pungent | 1 |
| 2.02 | meaty | 1 |
| 2.15 | roasted | 1 |
| 2.16 | rancid/poop | 1 |
| 2.48 | acid | 1 |
| 2.54 | acetic acid | 1 |
| 2.64 | acetic acid | 1 |
| 2.75 | sulfurous | 2.5 |
| 2.77 | roasted | 2.5 |
| 2.79 | roasted | 1.5 |
| 2.80 | musty | 1 |
| 3.46 | medicinal | 1 |
| 4.33 | cheesy | 2.5 |
| 4.50 | cheesy | 2 |
| 4.54 | cheesy/rancid | 1 |
| 4.65 | grassy | 2 |
| 4.73 | grassy | 1 |
| 5.35 | musty | 2.5 |
| 5.42 | cheesy | 3 |
| 5.50 | musty | 1.5 |
| 5.65 | medicinal | 1 |
| 5.98 | burnt | 1 |
| 6.01 | baked | 1.5 |
| 6.64 | fish | 1 |
| 6.70 | bad | 2.5 |
| 6.73 | chromium picolinate | 1.5 |
| 6.85 | vitamins | 1.5 |
| 6.90 | roasted | 2.5 |
| 7.54 | phenolic | 1 |
| 7.80 | plastic | 1 |
| 8.13 | phenolic | 1 |
| 8.48 | plastic | 2 |
| 8.47 | mushroom | 1 |
| 8.46 | phenolic/musty | 1 |
| 8.51 | burnt rubbery | 3 |
| 8.83 | fruity/banana | 1.5 |
| 8.93 | musty/moldy | 1 |
| 9.27 | chemical/phenolic | 2 |
| 10.01 | musty/moldy | 1 |
| 10.22 | cooked meat | 1.5 |
| 10.58 | earthy | 1 |
| 10.67 | earthy/ethereal | 1 |
| 10.80 | woody | 1 |
| 10.81 | burnt chemical | 1 |

| Rep 2 Treatment 3 Jungle | | |
|---|---|---|
| Rt | Aroma | Level |
| 1.47 | musty | 1 |
| 1.67 | musty/earthy/viney | 2 |
| 2.08 | stinky/pungent | 2 |
| 2.24 | rancid/sour | 3 |
| 2.38 | acetic acid | 3 |
| 2.44 | fruity/coconut | 1 |
| 2.61 | Sour | 3 |
| 2.73 | rancid/cheesy | 4 |
| 2.75 | earthy/acidic | 1 |
| 2.85 | moldy | 2 |
| 2.85 | floral/soury | 3 |
| 3.23 | spicy/earthy | 1 |
| 3.28 | musty/clamy | 1 |
| 3.78 | floral/earthy | 1 |
| 4.33 | Sour/vegetable | 1 |
| 4.52 | Fatty/rancid | 1.5 |
| 4.52 | chessy | 2 |
| 4.62 | stinky/earthy | 2 |
| 4.76 | grassy | 2 |
| 5.07 | nutty/plastic | 1 |
| 5.40 | stinky/putrid | 3 |
| 5.54 | wet dog/putrid | 2 |
| 5.58 | cabbage/cat food | 4 |
| 5.75 | musty | 1 |
| 5.77 | acidic | 2 |
| 5.99 | Sour/earthy | 1 |
| 6.16 | poultry/meaty | 3 |
| 6.17 | Fatty/graham cracker | 3 |
| 6.24 | Sour/rubbery | 3 |
| 6.50 | floral | 2 |
| 6.86 | chromium picolinate | 3 |
| 6.88 | Fatty/meaty | 3 |
| 6.94 | catfood/grainy/meaty | 2 |
| 7.29 | baked/nutty | 1 |
| 7.34 | grainy | 1 |
| 7.87 | ammonium/floral | 1 |
| 8.10 | geraniums/floral | 2 |
| 8.38 | Fatty | 2 |
| 8.42 | sulfurous/onion | 1 |
| 8.52 | sulfurous/ammonia | 2 |
| 8.52 | musty/moldy | 2 |
| 8.61 | metallic/sulfurous | 1 |
| 8.64 | medicinal | 1 |
| 8.72 | metallic | 1 |

| Rep 3 Treatment 3 | | |
|---|---|---|
| Rt | Aroma | Level |
| 1.25 | medicinal | 1 |
| 1.99 | earthy/moldy | 1 |
| 2.01 | pungent | 2 |
| 2.17 | sour/acid | 2 |
| 2.43 | vinegar | 3 |
| 2.54 | acetic acid | 1 |
| 2.66 | feed/grainy | 1.5 |
| 2.67 | peanut | 2 |
| 2.70 | cheesy/rancid | 1 |
| 2.81 | musty | 1 |
| 4.38 | cheesy/rancid | 4 |
| 4.39 | cheesy/rancid | 2 |
| 4.41 | earthy/moldy | 1 |
| 4.67 | grassy | 2 |
| 4.67 | grassy | 1 |
| 4.69 | grassy | 3 |
| 4.87 | fruity/floral | 1 |
| 5.37 | musty/stinky feet | 2 |
| 5.40 | stinky feet | 4 |
| 5.44 | wet dog | 2 |
| 5.60 | musty | 2 |
| 6.02 | creamy/cereal | 1.5 |
| 6.06 | roasted | 3 |
| 6.06 | poultry/meaty | 1 |
| 6.78 | potato chip | 2 |
| 6.80 | vitamin | 2 |
| 6.81 | chromium picolinate | 1 |
| 7.10 | baked/nutty | 1 |
| 7.67 | plastic | 1 |
| 7.76 | sweet | 1 |
| 7.93 | plastic | 1 |
| 8.32 | sulfurous/onion | 1 |
| 8.32 | cooked veggies | 1 |
| 8.38 | mushrooms | 1 |
| 8.48 | sulfurous/metallic | 2 |
| 8.51 | new shoes | 1 |
| 8.54 | herbal | 1 |
| 8.71 | phenolic | 1 |
| 8.72 | phenolic/medicinal | 2 |
| 9.33 | woody/moldy | 1 |
| 9.58 | roasted | 1 |
| 10.70 | baked/cereal | 1 |
| 10.72 | chocolate | 2 |
| 10.73 | earthy/woody | 1 |

| | | |
|---|---|---|
| 10.93 | earthy/wood | 1 |
| 10.99 | carmel/sweet | 1.5 |
| 11.22 | nutty/cooked meat | 1 |
| 11.26 | sweet | 1 |
| 11.26 | sweet | 1 |
| 11.63 | tacos | 1 |
| 12.02 | cooked meat | 1 |
| 12.17 | floral/earthy | 1 |
| 12.25 | baked aroma | 1 |
| 12.27 | burned/roasted | 1 |
| 12.38 | animal feed | 1 |
| 12.46 | floral/new shoes | 1 |
| 13.10 | phenolic | 1 |
| 14.07 | earthy | 1 |
| 14.93 | floral | 1 |
| 15.11 | rose/floral | 1.5 |
| 15.20 | grapes | 1 |
| 15.30 | floral | 1 |
| 16.39 | sweet | 1 |
| 17.99 | floral | 1 |
| 19.98 | sour | 1 |

| | | |
|---|---|---|
| 8.86 | floral | 1 |
| 9.18 | meaty/eggy | 1 |
| 9.37 | musty | 2 |
| 9.39 | phenolic | 1 |
| 9.77 | citrus | 1 |
| 9.91 | phenolic | 1 |
| 10.05 | metallic/earthy | 2 |
| 10.24 | Nutty | 2 |
| 10.42 | sweaty/stinky | 1 |
| 10.53 | sulfuruos/pungent | 1 |
| 10.73 | herbaceous | 1 |
| 10.83 | musty/baked | 2 |
| 10.85 | chocolate/coffee | 2 |
| 10.87 | earthy/nutty | 2 |
| 11.01 | musty | 1.5 |
| 11.07 | musty | 1 |
| 11.13 | sweet | 1.5 |
| 11.91 | citrus/floral | 1 |
| 12.29 | earthy/woody | 2 |
| 12.30 | earthy/coffee | 2 |
| 12.35 | roasted/nutty | 2 |
| 12.49 | Fresh/soapy | 1 |
| 12.64 | vegetable | 1 |
| 12.76 | baked/nutty/roasted | 3 |
| 12.76 | sulfurous/rotten egg | 1 |
| 12.82 | cereal/oily | 2 |
| 13.19 | sulfurous/metallic | 3 |
| 13.45 | vegetable/nutty | 1 |
| 13.55 | plastic | 1 |
| 13.86 | vegetable/spicy | 1 |
| 14.05 | grassy | 1 |
| 14.06 | rubbery/metallic | 2 |
| 14.46 | Nutty/musty | 1 |
| 14.76 | metallicy/earthy | 2 |
| 14.99 | bready | 1 |
| 15.25 | floral | 1 |
| 15.26 | floral/fruity | 2 |
| 15.34 | fruity | 1 |
| 15.41 | fruity | 2 |
| 15.45 | fruit/berry | 1 |
| 15.70 | floral/grassy | 1 |
| 15.85 | floral | 1 |
| 15.94 | fruity | 1 |
| 16.46 | metallic/stinky | 1 |
| 16.53 | Nutty/baked | 1 |
| 16.73 | musty | 1 |
| 16.89 | fruity/floral | 2 |
| 17.29 | plastic | 1 |

| | | |
|---|---|---|
| 11.09 | sweet/coffee | 1 |
| 12.16 | medicinal | 1 |
| 12.21 | earthy/woody | 1 |
| 12.22 | moth balls | 1 |
| 12.41 | floral | 1 |
| 12.66 | baked aroma | 2 |
| 12.93 | floral | 1 |
| 13.77 | moldy | 1 |
| 14.30 | earthy | 1 |
| 14.79 | plastic | 1 |
| 15.11 | grapes | 1.5 |
| 15.15 | grapes/fruity | 1.5 |
| 15.16 | almond | 1 |
| 15.37 | floral/fruity | 1 |
| 15.57 | floral | 1 |
| 15.98 | malty | 2 |
| 16.13 | cooked | 1 |
| 17.68 | phenolic | 1 |
| 18.65 | phenolic | 1 |
| 18.90 | phenolic | 1 |
| 19.41 | phenolic | 1.5 |
| 19.74 | phenolic | 1.5 |

| | | |
|---|---|---|
| 17.38 | floral | 1 |
| 17.67 | floral/rose | 1.5 |
| 18.01 | musty/metallic | 1 |
| 18.42 | vegetable | 1 |
| 18.62 | earthy/mossy | 2 |

| Rep 1 Treatment 4 Jungle | | | Rep 2 Treatment 4 Jungle | | | Rep 3 Treatment 4 Jungle | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 1.03 | phenolic | 1 | 1.43 | Citrus | 1 | 1.77 | woody/moldy | 1 |
| 1.57 | plastic | 1 | 1.87 | meaty/fatty | 1 | 1.80 | fishy | 4 |
| 1.82 | musty/cheesy | 1 | 1.96 | Sour | 1 | 2.16 | sour | 2 |
| 2.04 | roasted | 1 | 1.93 | Burnt | 1 | 2.18 | buttery | 1 |
| 2.05 | grainy/woody | 1 | 2.12 | Cheesy/buttery | 1 | 2.38 | sour/acidic | 3 |
| 2.13 | cheesy | 1 | 2.35 | Acidic | 1.5 | 2.54 | stinky feet | 2 |
| 2.29 | sour/acid | 1 | 2.61 | pungent | 2.5 | 2.65 | baked cereal/feed | 2 |
| 2.31 | acetic acid | 2 | 2.73 | Musty | 1.5 | 2.66 | pungent | 2 |
| 2.62 | pungent/poop | 1 | 2.77 | Soapy | 1 | 4.15 | cheesy | 4 |
| 2.63 | roasted | 2.5 | 2.77 | grainy/poultry | 3 | 4.35 | cheesy | 3 |
| 2.65 | grainy/fritos | 1 | 3.40 | Earthy | 1 | 4.47 | sweet | 1 |
| 4.39 | rancid/cheesy | 1 | 3.55 | vegetable | 1 | 4.52 | cheesy | 3 |
| 4.46 | cheesy | 1 | 3.74 | Spicy | 1 | 4.67 | grassy | 1.5 |
| 4.82 | phenolic | 1 | 4.27 | Cheesy/buttery | 1 | 4.67 | grassy | 2 |
| 5.38 | musty | 2 | 4.45 | Floral | 1 | 5.19 | soured | 3 |
| 5.39 | cheesy/rancid | 2 | 4.64 | fatty/grainy | 2 | 5.37 | musty/stinky feet | 2 |
| 5.39 | fecal/putrid | 1 | 4.70 | Grass | 1 | 5.40 | wet dog | 2 |
| 5.57 | sweaty | 1.5 | 4.75 | phenolic | 1 | 5.60 | musty | 1 |
| 5.56 | rancid/cheesy | 2 | 4.86 | vegetable | 1 | 5.90 | nutty | 1 |
| 5.93 | burnt | 1 | 5.03 | Minty | 1 | 6.04 | nutty/baked | 1 |
| 6.04 | baked | 1 | 5.38 | Nutty | 1 | 6.12 | roasted | 1 |
| 6.68 | fishy | 1 | 5.44 | Rancid | 3 | 6.23 | phenolic | 1 |
| 6.75 | vitamins | 2 | 5.50 | pungent/rancid | 5 | 6.65 | potato chip | 2 |
| 6.76 | chromium picolinate | 2 | 5.55 | sour cheese/rancid | 3 | 6.66 | poultry | 1 |
| 6.92 | roasted | 2 | 5.66 | Cheesy/rancid | 2 | 6.73 | roasted | 2 |
| 7.03 | medicinal | 1 | 6.10 | Woody | 1 | 6.79 | chromium picolinate | 2 |
| 7.12 | fritos | 1 | 6.83 | chromium picolinate | 2 | 6.80 | vitamins | 2 |
| 7.14 | nutty/roasted | 1.5 | 6.90 | meaty/poultry | 5 | 7.09 | plastic | 1 |
| 7.79 | sweet | 1 | 7.20 | nutty/baked | 1.5 | 7.10 | salty | 1 |
| 8.35 | mushrooms | 1 | 7.21 | Nutty | 1 | 7.14 | nutty | 2 |
| 8.37 | dirt | 1 | 8.16 | peanutty | 1 | 7.16 | creamy | 1 |
| 8.41 | plastic | 2 | 8.34 | Sweat | 1 | 7.55 | fruity | 2 |
| 8.49 | plastic | 1 | 8.39 | sulfurous | 2 | 8.22 | grape | 1 |
| 8.49 | sulfurous | 1 | 8.48 | sulfurous/metallic | 3 | 8.28 | sulfurous | 2 |
| 8.92 | lemon/citrus | 2 | 8.55 | floral/viney | 2 | 8.29 | phenolic | 1 |
| 10.68 | earthy/nutty | 1 | 8.57 | metallic | 3 | 8.37 | mushrooms | 1 |
| 10.70 | roasted | 1 | 8.95 | Floral | 2 | 8.42 | sulfurous/metallic | 3 |
| 10.96 | phenolic | 2 | 9.15 | floral/woddy | 3 | 8.48 | urine | 1 |
| 10.99 | sweet/carmel | 1.5 | 9.58 | Fruity | 1 | 8.49 | plastic | 1.5 |
| 11.02 | burned | 1 | 9.90 | Roasted | 1 | 9.08 | baked cereal | 1 |
| 11.27 | sweet | 1 | 10.14 | baked/nutty | 1 | 9.92 | malty | 5 |
| 11.94 | soapy | 1 | 10.50 | Roasted | 1 | 10.40 | malty | 3 |
| 12.12 | earthy/woody | 1 | 10.79 | musty/moldy | 1.5 | 10.66 | burnt | 3 |

| | |
|---|---|
| 12.15 viney | 1 |
| 12.16 cooked meat | 1 |
| 12.30 phenolic | 1 |
| 12.62 phenolic | 1 |
| 12.84 floral | 1 |
| 12.95 medicinal | 1 |
| 13.68 fruity | 1 |
| 15.11 floral | 1 |
| 15.18 grapes | 1 |
| 15.30 floral | 1 |
| 15.89 plastic | 1 |
| 16.01 new shoes | 1 |
| 16.07 lemon | 1 |
| 16.38 phenolic | 1 |
| 16.51 new shoes | 1 |
| 16.92 phenolic | 1 |
| 18.94 floral | 1 |

| | |
|---|---|
| 10.89 herbacceous/nutty | 1 |
| 11.10 sweet/caramel | 2 |
| 11.22 Sour | 1 |
| 11.28 Sweet | 1 |
| 11.68 metallic | 1 |
| 12.26 Floral | 1 |
| 12.29 Earthy | 1 |
| 12.33 nutty/honey | 2 |
| 12.34 coffee/earthy | 3 |
| 12.49 Floral | 1 |
| 12.75 baked/nutty | 2.5 |
| 12.84 grainy/fatty | 3 |
| 13.45 Cheesy/spicy | 5 |
| 14.30 Musty | 1 |
| 14.70 vegetable/herbaceous | 1 |
| 14.88 Fruity | 1 |
| 15.22 fruity/floral | 2 |
| 15.25 Grapes/fruity | 3 |
| 15.79 stinky/metallic | 1 |
| 15.81 metallic | 1 |
| 16.73 Fruity | 1 |
| 16.73 musty/metallicy | 1 |
| 17.48 musty | 1 |
| 17.81 Viney/earthy | 1 |
| 18.72 Citrus | 1 |
| 19.20 Fatty | 1 |

| | |
|---|---|
| 10.69 earthy | 1 |
| 10.70 earthy | 3 |
| 11.10 sweet/caramel | 1 |
| 12.19 sweet | 1 |
| 12.19 cooked vegetable | 2 |
| 12.20 medicinal | 1 |
| 12.37 floral | 1 |
| 12.45 alcohol | 1 |
| 13.17 pyridine | 1 |
| 15.11 floral/grape | 1 |
| 15.15 fruity | 1 |
| 15.40 medicinal | 1 |
| 15.47 grapes | 1.5 |
| 19.17 phenolic | 1 |

Rep 1 Treatment 5 Jungle

| Rt | Aroma | Level |
|---|---|---|
| 1.79 | musty/cheesy | 1 |
| 1.84 | musty | 1 |
| 2.04 | roasted | 1 |
| 2.07 | rotten/pungent | 1 |
| 2.18 | cheesy | 1.5 |
| 2.40 | cheesy/rancid | 1 |
| 2.64 | pungent/putrid | 2 |
| 2.66 | roasted | 2 |
| 2.67 | grainy/woody | 1 |
| 2.78 | musty/moldy | 2 |
| 2.81 | plastic | 1 |
| 4.08 | phenolic | 1 |
| 4.30 | cheesy/rancid | 2 |
| 4.37 | cheesy/rancid | 1 |
| 4.65 | grassy | 1 |
| 4.68 | fruity | 1 |
| 5.26 | grassy | 1 |
| 5.39 | musty | 2 |
| 5.43 | cheesy | 1 |
| 5.44 | stinky cheese | 1 |
| 5.57 | moldy/musty | 2 |
| 6.04 | baked/nutty | 1 |
| 6.67 | meaty | 1 |
| 6.70 | musty | 2 |
| 6.76 | chromium picolinate | 1.5 |
| 6.79 | vitamins | 1 |
| 6.80 | roasted | 2 |
| 7.15 | baked/nutty | 1 |
| 7.18 | fritos | 1 |
| 8.27 | sulfurous/meaty | 1 |
| 8.38 | grassy | 1 |
| 8.41 | plastic | 1 |
| 8.46 | rubbery/plasticy | 2 |
| 8.48 | sulfurous/ammonia | 2 |
| 8.52 | plastic | 1 |
| 8.94 | lemon | 1.5 |
| 9.41 | plastic | 1 |
| 10.42 | phenolic | 1 |
| 10.60 | plastic | 1 |
| 10.60 | moldy/musty | 1 |
| 10.68 | coffee | 1.5 |
| 10.73 | chemical | 1 |
| 10.74 | burnt meat | 2 |
| 10.83 | plastic | 1 |

Rep 2 Treatment 5 Jungle

| Rt | Aroma | Level |
|---|---|---|
| 1.43 | metallic | 1 |
| 1.67 | butter | 1 |
| 1.73 | acidic | 1 |
| 1.79 | nutty/meaty | 2 |
| 1.90 | cooked | 1 |
| 1.96 | metallic/musty | 1 |
| 2.20 | nutty | 1 |
| 2.21 | nutty | 1 |
| 2.29 | sour/acid | 1 |
| 2.36 | acetic acid | 3 |
| 2.38 | fatty/sour | 1 |
| 2.52 | sour | 3 |
| 2.59 | nutty/chocolate | 1 |
| 2.65 | floral/earthy | 2 |
| 2.74 | fatty/chessy | 3 |
| 2.77 | cheesy/rancid | 4 |
| 2.88 | musty | 1 |
| 3.09 | mint | 1 |
| 3.13 | earthy/grassy | 1 |
| 3.31 | mossy/floral/viney | 2 |
| 3.87 | stinky/putrid | 2 |
| 4.05 | sweet | 1 |
| 4.37 | mushrooms/mossy | 1 |
| 4.45 | fatty | 1 |
| 4.47 | cheesy | 2 |
| 4.59 | fatty | 2 |
| 4.68 | floral | 1 |
| 4.80 | grassy | 1 |
| 4.84 | floral | 1 |
| 5.22 | roasted | 1 |
| 5.41 | cereal | 2 |
| 5.52 | poultry/meaty | 1 |
| 5.54 | sour/cheesy | 3 |
| 5.72 | musty | 2 |
| 5.78 | floral | 1 |
| 6.14 | phenolic | 1 |
| 6.15 | clammy | 1 |
| 6.20 | nutty/baked | 1 |
| 6.30 | meaty/nutty | 3 |
| 6.30 | spicy | 1 |
| 6.53 | vegetable | 1 |
| 6.80 | woody | 1 |
| 6.86 | boiled poultry | 1.5 |
| 6.91 | chromium picolinate | 4 |

Rep 3 Treatment 5 Jungle

| Rt | Aroma | Level |
|---|---|---|
| 1.76 | burnt | 1 |
| 2.13 | oily/dirty | 1 |
| 2.20 | rancid | 2 |
| 2.36 | sour/acidic | 4 |
| 2.65 | baked/grainy | 1.5 |
| 2.68 | pungent | 3 |
| 2.70 | stinky feet | 2 |
| 2.82 | mushrooms/moldy | 1 |
| 3.08 | nutty | 1 |
| 3.16 | sweet cream | 1 |
| 4.34 | cheesy | 4 |
| 4.39 | moldy/earthy | 1 |
| 4.40 | cheesy | 3 |
| 4.65 | green | 1 |
| 4.68 | grassy/green | 4 |
| 5.38 | musty/stinky feet | 2 |
| 5.39 | stinky feet | 3 |
| 5.43 | sulfurous | 2 |
| 5.65 | musty | 1 |
| 5.65 | creamy | 1 |
| 5.66 | raw peanut | 1 |
| 6.00 | bell pepper | 1 |
| 6.12 | nutty | 1 |
| 6.35 | baked cookie | 1 |
| 6.46 | fruity | 1 |
| 6.72 | vitamins | 2.5 |
| 6.73 | poultry | 1 |
| 6.75 | potato baked | 2 |
| 6.82 | chromium picolinate | 1 |
| 6.98 | baked bread | 1 |
| 7.14 | roasted | 1 |
| 7.16 | fried | 1 |
| 7.24 | nutty/baked | 1 |
| 7.54 | phenolic/chemical | 1 |
| 8.36 | sulfurous | 1 |
| 8.38 | mushrooms | 1 |
| 8.47 | plastic | 1.5 |
| 8.49 | sulfurous/metallic | 2 |
| 8.50 | fruity | 1 |
| 8.56 | metallic | 3 |
| 8.70 | cherry | 1 |
| 9.63 | fatty/oily | 1 |
| 10.53 | roasted/cereal | 1 |
| 10.69 | earthy | 1 |

| | | |
|---|---|---|
| 10.99 | sweet/caramel | 1.5 |
| 11.17 | sweet feed | 1 |
| 11.29 | sweet | 1 |
| 12.16 | earthy | 1.5 |
| 12.19 | grainy/feed | 1 |
| 12.20 | roasted | 2 |
| 12.26 | plastic | 1 |
| 12.35 | floral | 1.5 |
| 14.07 | floral | 1 |
| 15.11 | floral/sweet | 1 |
| 15.14 | grapes | 1 |
| 15.37 | floral | 1 |
| 17.30 | phenolic | 1 |

| | | |
|---|---|---|
| 6.92 | lemon | 1 |
| 6.94 | catfood/grainy | 2 |
| 7.33 | nutty/baked | 2 |
| 7.62 | fatty/meaty | 1 |
| 7.78 | herbacceous | 1 |
| 8.07 | phenolic | 1 |
| 8.13 | floral/sweet | 1 |
| 8.39 | roasted | 1 |
| 8.40 | sulfur/onion | 2 |
| 8.50 | rubbery | 1 |
| 8.54 | sulfurous/metallic | 3 |
| 8.58 | floral/herbaceous | 1 |
| 8.69 | metacllic | 1 |
| 8.75 | metallic/earthy | 2 |
| 9.00 | meaty/poultry | 1 |
| 9.20 | beans | 1 |
| 9.41 | fruity/cherry/berry | 1 |
| 9.60 | metallic | 1 |
| 9.98 | lemon | 1 |
| 10.27 | meaty/nutty | 1 |
| 10.45 | musty | 1 |
| 10.67 | nutty | 1 |
| 10.78 | nutty/woody | 3 |
| 10.88 | earthy/grassy | 2 |
| 10.93 | earthy | 1 |
| 11.20 | floral/sweet | 2 |
| 11.40 | nutty/sweet/caramel | 3 |
| 12.12 | citrus | 1 |
| 12.33 | earthy/woody | 2 |
| 12.35 | balsamic | 1 |
| 12.42 | nutty/roasted | 2 |
| 12.50 | medicinal | 1.5 |
| 12.69 | fruity | 1 |
| 12.80 | baked/nutty | 1 |
| 12.84 | cereal/bready | 1 |
| 13.59 | sour | 1 |
| 15.03 | sweet | 1 |
| 15.27 | fruity | 1 |
| 15.34 | sweet | 1 |
| 15.45 | fruity | 3 |
| 15.76 | sweet | 1 |
| 16.02 | cabbage | 1 |
| 16.19 | sweaty/stinky | 2 |
| 16.51 | earthy/rooty | 1 |
| 16.85 | earthy/mossy | 1 |
| 17.14 | chocolate | 1 |
| 17.80 | fruity | 1 |
| 17.80 | metallic/floral | 1 |

| | | |
|---|---|---|
| 10.74 | musty | 1 |
| 10.79 | burnt/plastic | 2 |
| 11.08 | sweet/caramel | 1 |
| 11.14 | sweet/baking | 1 |
| 11.24 | roasted/baked | 2 |
| 12.00 | alcohol | 1 |
| 12.16 | dirt | 2 |
| 12.18 | earthy/moldy | 1 |
| 12.31 | earthy | 1 |
| 12.48 | phenolic | 1 |
| 13.19 | fruity | 1 |
| 13.20 | plastic | 1 |
| 13.77 | sweet | 1 |
| 14.30 | alcohol | 1 |
| 15.14 | floral | 1 |
| 15.61 | sweet | 1 |
| 16.16 | moldy | 1 |
| 16.39 | sweet/fruity | 1 |
| 16.47 | fruity | 1 |
| 16.93 | roasted | 1 |
| 17.84 | floral | 1 |
| 18.00 | sweet/candy | 1 |
| 18.60 | phenolic | 1 |

| | |
|---|---|
| 18.10 citrus | 1 |
| 18.16 meaty | 1 |
| 18.37 earthy/herbacceous | 2 |
| 18.58 mossy | 3 |
| 19.21 fruity | 1 |
| 19.73 mossy/woody | 1 |

| Rep 1 Treatment 6 Jungle | | | Rep 2 treatment 6 Jungle | | | Rep 3 Treatment 6 Jungle | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 1.51 | rancid | 1 | 1.31 | stinky | 1 | 1.78 | moldy/mushrooms | 1.5 |
| 1.94 | roasted | 1 | 1.48 | burnt | 1 | 1.80 | cat urine | 1 |
| 2.04 | nutty | 1 | 1.58 | earthy | 1 | 1.96 | vegetable | 1 |
| 2.19 | rancid/acid | 2.5 | 1.89 | meaty | 2 | 2.19 | sour/acidic | 2 |
| 2.33 | acid/sour | 2.5 | 2.12 | sour | 1 | 2.40 | sour | 1 |
| 2.54 | roasted | 2 | 2.20 | sweat | 2 | 2.62 | vegetable | 1 |
| 2.64 | grainy/fritos | 1 | 2.29 | sour/cheesy | 4 | 2.66 | stinky feet | 2 |
| 2.67 | pungent/putrid | 3 | 2.38 | sulfury/spicy | 3 | 2.66 | roasted/grainy | 2 |
| 2.79 | musty | 1 | 2.53 | cheesy | 4 | 2.75 | vegetable | 1 |
| 4.10 | floral | 1 | 2.53 | fruity | 1 | 4.35 | cheesy | 1.5 |
| 4.33 | cheesy/musty | 1 | 2.77 | pungent | 3 | 4.38 | cheesy | 3 |
| 4.42 | cheesy | 1 | 2.80 | citrus | 1 | 4.38 | cheesy | 2 |
| 4.50 | cheesy | 2 | 2.81 | fatty/cheesy | 3 | 4.63 | green/herbacceous | 1 |
| 4.60 | grassy | 1 | 2.88 | musty | 1.5 | 4.69 | grassy | 2 |
| 4.66 | grassy | 2 | 3.11 | ethereal/mossy | 1 | 5.34 | stinky feet/sweaty | 1.5 |
| 5.29 | rancid | 2 | 3.21 | fruity | 1 | 5.36 | musty/stinky feet | 1 |
| 5.39 | musty | 2 | 3.57 | balsamic | 2 | 5.42 | stinky feet | 4 |
| 5.42 | cheesy/musty | 1 | 4.20 | fruity | 1 | 6.00 | nutty | 1 |
| 5.55 | rancid | 1 | 4.56 | fatty/cheesy | 2 | 6.05 | nutty | 1 |
| 5.61 | musty | 1.5 | 4.63 | rancid | 3 | 6.63 | poultry | 1 |
| 5.79 | sweet | 1.5 | 4.80 | grassy | 2 | 6.72 | vitamins | 2 |
| 6.05 | roasted/baked | 1 | 5.18 | sweet | 1 | 6.73 | chromium picolinate | 2 |
| 6.19 | sweet | 1 | 5.25 | stinky/fatty | 2 | 6.75 | potato chips | 3 |
| 6.48 | herby | 1 | 5.52 | sour/cheesy | 2 | 7.09 | sweet/roasted | 1 |
| 6.61 | vegetable | 2 | 5.53 | musty | 2 | 7.13 | baked cereal | 1.5 |
| 6.67 | boiled poultry | 1 | 5.55 | citrus | 1 | 7.18 | cooked | 1 |
| 6.70 | roasted | 2 | 5.76 | musty/moldy | 2 | 7.26 | sweet | 1 |
| 6.79 | vitamins | 2 | 6.18 | baked | 1 | 7.71 | fruity | 1 |
| 6.80 | chromium picolinate | 2 | 6.24 | poultry/meaty | 1 | 8.35 | mushrooms | 1 |
| 6.85 | medicinal | 1 | 6.28 | chocolate | 1 | 8.38 | vegetable | 1 |
| 7.15 | baked/cereal | 1 | 6.44 | roasted/stinky | 1 | 8.47 | plastic | 1.5 |
| 7.15 | roasted/burnt | 1 | 6.81 | poultry/meaty | 2 | 10.65 | burnt/stinky | 3 |
| 7.19 | creamy | 1 | 6.91 | chromium picolinate | 3 | 10.70 | earthy | 1 |
| 7.84 | sweet | 1 | 6.93 | grainy/fatty | 3 | 10.74 | dirt | 1 |
| 8.04 | phenolic | 1 | 7.17 | catfood/grainy | 3 | 11.12 | creamy/cereal | 1 |
| 8.27 | sulfurous | 1 | 7.42 | catfood | 1 | 11.76 | sweet | 1 |
| 8.30 | plastic | 2 | 8.02 | floral | 1 | 12.16 | musty/earthy | 1 |
| 8.38 | mushrooms | 1.5 | 8.39 | musky | 1 | 12.18 | earthy | 1 |
| 8.39 | sulfurous/ammonia | 2 | 8.41 | metallic/waxy | 1 | 12.21 | musty | 2 |
| 8.42 | rubbery | 2 | 8.41 | sulfurous/onion | 2 | 13.48 | alcohol | 1 |
| 8.49 | grassy/sulfurous | 2 | 8.46 | fatty | 1 | 14.36 | plastic | 1 |
| 8.52 | plastic | 1 | 8.54 | sulfurous/metallic | 3 | 15.11 | floral | 1 |
| 8.82 | sweet | 1 | 8.59 | metallic/rubbery | 3 | 15.11 | fruity | 1 |
| 8.82 | roasted | 1 | 8.64 | metallic | 1 | 15.27 | fruity/grapes | 1 |

| | |
|---|---|
| 10.02 sweet | 1 |
| 10.67 roasted/baked | 1 |
| 10.69 baked | 1 |
| 10.72 woody | 1 |
| 10.97 sweet/caramel | 2 |
| 11.09 fruity/grapes | 2 |
| 11.29 sweet | 1 |
| 11.35 fruity | 1 |
| 11.46 musty | 1 |
| 12.09 roasted | 1 |
| 12.19 musty | 1 |
| 12.34 floral | 1 |
| 12.55 earthy | 1 |
| 12.76 phenolic | 1 |
| 14.70 floral | 1 |
| 15.06 floral | 2 |
| 15.12 floral | 1 |
| 15.20 floral/plastic | 1 |
| 15.28 sweet/fruity | 1 |
| 15.51 new shoes | 1 |
| 15.55 phenolic | 1 |
| 16.00 new shoes | 1 |
| 16.76 floral | 1 |
| 16.95 phenolic | 1 |
| 17.71 phenolic/medicinal | 1 |
| 17.87 sour | 1 |

| | |
|---|---|
| 8.77 earthy | 1 |
| 9.25 spicy | 1 |
| 9.55 sweet | 1 |
| 9.55 mossy | 2 |
| 9.95 balsamic | 1 |
| 10.20 cereal | 1 |
| 10.66 floral | 1 |
| 10.67 hazelnut | 1 |
| 10.70 nutty | 2 |
| 10.86 earthy/woody | 2 |
| 10.89 nutty/sweet | 3 |
| 10.92 earthy | 1 |
| 10.95 vegetable | 1 |
| 11.32 earthy/ethereal | 2 |
| 11.54 meaty | 1 |
| 11.65 baked | 1 |
| 11.78 sweet | 1 |
| 11.93 catfood | 1 |
| 11.95 cooked | 1 |
| 12.29 nutty | 3 |
| 12.33 woody | 2 |
| 12.38 caramel/syrup | 1 |
| 12.56 grassy/woody | 2 |
| 12.64 sweet | 1 |
| 12.79 nutty | 1 |
| 12.81 nutty | 1.5 |
| 12.84 meaty/poultry | 1 |
| 13.19 floral | 1 |
| 13.35 fruity | 1 |
| 13.45 citrus | 1 |
| 13.62 fruity/floral | 1 |
| 13.74 musty | 1 |
| 13.83 cereal | 1 |
| 14.07 sweaty | 2 |
| 14.11 sweet | 1 |
| 14.39 cereal | 1 |
| 14.45 fruity | 1 |
| 14.72 musty/moldy | 2 |
| 15.00 sweet | 1 |
| 15.30 fruity | 3 |
| 15.30 fruity | 1 |
| 15.32 fruity | 1 |
| 15.40 floral | 1 |
| 15.55 sour | 1 |
| 15.93 floral | 2 |
| 15.99 musty | 1 |
| 16.45 musty | 1 |
| 16.47 nutty | 1 |

| | |
|---|---|
| 15.33 floral | 1 |
| 16.40 medicinal | 1 |
| 16.84 floral | 1.5 |
| 17.05 rubber | 1 |
| 17.99 sweet | 1 |

| | | |
|---|---|---|
| 16.63 | citrus | 1 |
| 16.98 | roasted/cereal | 1 |
| 17.00 | plastic | 1 |
| 17.20 | musty | 3 |
| 17.70 | fruity | 1 |
| 18.11 | sweet | 1 |
| 18.33 | cooked | 1 |
| 19.02 | cabbage | 1 |
| 19.03 | musty | 1 |
| 19.39 | musty | 2 |
| 19.60 | caramel | 1 |
| 19.88 | lemon | 1 |

# APPENDIX G
# GC-O AMBIENT CONDITIONS

| Rep 1 Treatment 1 Ambient | | | Rep 2 Treatment 1 Ambient | | | Rep 3 Treatment 1 Ambient | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 0.87 | phenolic | 1 | 1.45 | musty | 1 | 1.34 | floral | 1 |
| 1.39 | sweet | 1 | 2.40 | floral | 1 | 1.62 | musty | 1 |
| 2.40 | vegetable | 1 | 2.48 | baked/roasted | 1 | 1.81 | roasted | 2 |
| 2.44 | acetic acid | 1 | 2.63 | feed/baked | 1 | 1.86 | earthy/moldy | 1 |
| 2.60 | plastic | 2 | 2.67 | roasted | 2 | 1.95 | buttery/sweet | 2 |
| 2.63 | roasted/nutty | 1 | 2.70 | feremented | 1 | 2.08 | sour | 1 |
| 4.40 | cheesy | 4 | 3.27 | burnt cracker | 1 | 2.20 | acetic acid | 1 |
| 4.43 | cheesy | 1 | 3.71 | nutty/musty | 1 | 2.29 | sour | 1.5 |
| 4.44 | stinky feet | 1 | 3.98 | medicinal | 1 | 2.40 | roasted/baked | 3 |
| 4.55 | rancid/cheesy | 1 | 4.32 | rancid/cheesy | 2 | 2.57 | perfumey | 2 |
| 4.70 | green | 2 | 4.50 | cheesy | 1 | 2.59 | putrid/rancid | 2.5 |
| 4.90 | asphalt smell | 1 | 4.52 | cheesy | 1.5 | 2.61 | grainy/feed | 1 |
| 4.94 | plastic | 2 | 4.73 | musty | 1 | 2.97 | plastic | 1 |
| 5.40 | stinky feet | 4 | 5.38 | cheesy | 2 | 3.08 | baked | 1 |
| 5.44 | chessy/rancid | 2 | 5.45 | musty | 1.5 | 3.64 | earthy/mushrooms | 1 |
| 5.44 | musty/stinky feet | 2 | 5.53 | stinky feet | 1 | 3.83 | cheese | 1 |
| 5.63 | phenolic | 1 | 6.75 | nutty/baked | 2 | 4.33 | cheesy | 2 |
| 5.81 | vegetable oil | 2 | 6.75 | vitamins | 2.5 | 4.35 | cheesy | 1 |
| 6.66 | old tennis shoes | 2 | 6.83 | potato chip | 3 | 4.40 | rancid/cheesy | 2 |
| 6.79 | roasted | 2 | 6.95 | medicinal | 1 | 4.43 | cheesy/rancid | 2 |
| 6.81 | potato chips | 2 | 7.10 | roasted | 1 | 4.56 | stinky shoes | 1 |
| 6.83 | vitamins | 3 | 7.17 | fritos | 1 | 4.99 | rancid/cheesy | 1 |
| 6.90 | vitamins/roasted | 3 | 7.45 | hexanal | 1 | 5.31 | wet dog | 2 |
| 7.23 | fritos | 2 | 8.39 | black pepper | 1 | 5.39 | cheesy/rancid | 3 |
| 7.81 | floral | 1 | 8.49 | grassy/onion | 2 | 5.45 | plastic | 1 |
| 8.46 | mushrooms | 1 | 8.51 | phenolic/chemical | 2 | 5.51 | musty | 1.5 |
| 8.51 | moldy | 1 | 8.79 | plastic | 1 | 5.60 | fruity | 1 |
| 8.56 | plastic | 2 | 8.96 | plastic | 1 | 6.62 | roasted/meaty | 2 |
| 8.81 | moldy | 2 | 9.93 | fruit | 1 | 6.65 | chromium picolinate | 2 |
| 9.20 | floral | 1 | 10.09 | sweet | 1.5 | 6.73 | roasted | 1.5 |
| 10.00 | fruity | 1 | 10.58 | earthy | 1 | 6.78 | roasted/vitamins | 3 |
| 10.08 | sweet | 1.5 | 10.73 | earthy/mushrooms | 1.5 | 7.03 | nutty | 1 |
| 10.66 | dirt | 2 | 10.77 | dirt | 1 | 7.39 | burnt | 2 |
| 10.70 | baked/burnt | 1 | 10.87 | phenolic | 1 | 7.63 | earthy | 1 |
| 10.76 | earthy | 1 | 11.12 | medicinal | 1 | 8.26 | sour | 1 |
| 11.33 | feed | 1 | 11.30 | sweet | 1 | 8.32 | sulfurous | 1 |
| 12.18 | baked | 2 | 12.04 | earthy/moldy | 1 | 8.33 | mushrooms | 2 |
| 12.21 | earthy | 2 | 12.20 | baked | 1 | 8.37 | rubbery/chemically | 2 |
| 12.25 | earthy/moldy | 1 | 12.22 | earthy | 1.5 | 8.42 | plastic | 2 |
| 12.44 | grape | 1 | 12.29 | malty | 1 | 8.49 | chemically | 3 |
| 12.46 | phenolic | 1 | 12.43 | plastic | 1 | 8.98 | earthy | 1 |
| 12.69 | phenolic | 2 | 13.92 | putrid | 1 | 9.18 | baked | 1 |

| | |
|---|---|
| 14.39 floral | 1 |
| 14.45 musty/stinky feet | 1 |
| 15.12 clothes dryer | 1 |
| 15.47 feed/grainy | 1 |
| 15.70 spicy | 2 |
| 15.97 plastic | 1 |
| 16.46 cardboard | 1 |
| 17.09 phenolic | 1 |
| 17.28 malty | 1 |
| 17.93 plastic | 1 |
| 18.13 sulfurous | 1 |
| 18.40 chemical/phenolic | 1 |
| 18.61 clothes dryer | 1 |
| 18.92 plastic | 1 |

| | |
|---|---|
| 14.60 earthy | 1 |
| 15.19 plastic | 1.5 |
| 15.39 stink bug | 2 |
| 15.89 clothes dryer | 1.5 |
| 16.64 cardboard | 1 |
| 17.63 sweet | 1 |

| | |
|---|---|
| 9.32 burnt | 2 |
| 10.00 baked cookie | 1 |
| 10.64 roasted grain | 1 |
| 11.34 earthy | 1 |
| 11.82 burnt/chemically | 1 |
| 12.05 earthy | 1 |
| 12.11 grassy/green | 1 |
| 12.21 roasted | 2 |
| 12.24 floral | 1.5 |
| 12.39 rubbery | 1 |
| 12.65 woody | 1 |
| 13.02 sweet | 1 |
| 13.78 cheesy/rancid | 1 |
| 14.35 earthy | 1 |
| 14.49 baked/roasted | 1 |
| 14.52 musty | 1 |
| 16.87 baked | 1 |
| 17.28 vanilla | 1 |
| 17.45 grainy/earthy | 1 |
| 17.54 grainy | 1 |
| 18.04 floral | 1 |
| 18.91 plastic | 1 |
| 19.08 baked | 1 |
| 19.25 musty | 1 |
| 19.35 plastic | 1 |
| 19.39 roasted | 1 |

| Rep 1 Treatment 2 Ambient | | | Rep 2 Treatment 2 Ambient | | | Rep 3 Treatment 2 Ambient | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 0.94 | sweet1 | | 0.89 | floral | 1 | 0.69 | plastic | 1 |
| 1.24 | raw peanut | 1 | 1.68 | musty | 1 | 1.65 | meaty | 1 |
| 1.80 | musty | 1 | 1.70 | plastic | 1 | 1.69 | musty | 1 |
| 1.85 | earthy | 1 | 1.77 | burnt | 1 | 1.76 | musty | 1 |
| 1.88 | soured | 1 | 1.77 | musty | 1 | 1.80 | earthy/mushrooms | 1 |
| 2.10 | plastic | 1 | 2.29 | plastic | 1.5 | 1.86 | musty | 1 |
| 2.59 | sweet | 1 | 2.58 | roasted | 2 | 1.97 | roasted | 1 |
| 2.62 | roasted | 1 | 2.67 | feed/grain | 1 | 1.99 | plastic | 1 |
| 2.70 | feed/grainy | 2 | 2.74 | roasted | 2 | 2.27 | sour/tart | 2.5 |
| 2.86 | plastic | 1 | 4.15 | plastic | 1 | 2.51 | putrid | 3 |
| 2.97 | new shoes | 1 | 4.27 | medicinal | 1 | 2.63 | grainy/baked | 1 |
| 3.29 | plastic | 1 | 4.47 | cheesy | 1 | 2.64 | baked/roasted | 3.5 |
| 3.60 | urine like | 1 | 4.48 | cheesy | 1 | 2.69 | sour | 3 |
| 3.66 | nutty | 1 | 4.69 | grassy | 2 | 2.79 | rancid | 1 |
| 4.30 | burnt/roasted | 1 | 4.95 | malty | 1 | 4.29 | roasted | 1 |
| 4.37 | cheesy | 4 | 5.03 | plastic | 1 | 4.34 | cheesy | 1.5 |
| 4.38 | cheesy | 1 | 5.41 | cheesy/rancid | 2 | 4.36 | cheesy/rancid | 4 |
| 4.60 | cooked | 1 | 5.46 | musty | 1 | 4.42 | cheesy/rancid | 2 |
| 4.92 | pungent | 1 | 6.02 | nutty/baked | 1 | 4.48 | cheesy/rancid | 1 |
| 5.33 | baked | 1 | 6.09 | roasted | 1.5 | 4.50 | grassy | 2 |
| 5.41 | stinky feet | 3 | 6.60 | roasted | 1 | 5.27 | rancid | 4 |
| 5.42 | stinky feet/musty | 1.5 | 6.68 | plastic/baked | 2 | 5.40 | musty/stinky feet | 3 |
| 5.45 | meaty | 1 | 6.78 | roasted | 3 | 5.46 | rancid/cheesy | 3 |
| 6.04 | baked/burnt | 1 | 6.78 | vitamins | 1.5 | 5.95 | stinky | 2 |
| 6.09 | nutty | 2 | 6.78 | potato chip | 4 | 6.06 | nutty | 2 |
| 6.79 | roasted | 2 | 7.18 | fritos/corn chips | 1 | 6.49 | boiled poultry | 2 |
| 6.81 | vitamins | 2 | 7.50 | fruity | 1 | 6.61 | chromium picolinate | 3 |
| 6.84 | potato chip | 2 | 7.92 | earthy/mushrooms | 1 | 6.69 | musty | 3 |
| 6.89 | roasted | 2 | 8.18 | phenolic | 1 | 6.72 | roasted | 2 |
| 7.09 | plastic | 1 | 8.30 | cooked vegetable oil | 1 | 6.73 | vitamins | 3 |
| 7.20 | dirt | 1 | 8.42 | musty | 2 | 6.82 | roasted | 3 |
| 7.23 | sweet/creamy | 1.5 | 8.42 | mushrooms | 1.5 | 6.97 | nutty/baked | 2.5 |
| 7.40 | green beans | 1 | 8.50 | rooty | 1 | 7.10 | fritos | 2 |
| 8.44 | baked | 1 | 8.51 | plastic | 1.5 | 7.35 | sweet | 2 |
| 8.46 | mushrooms | 1 | 9.55 | musty | 1 | 7.36 | plastic | 1.5 |
| 8.74 | plastic | 1 | 10.37 | floral | 1 | 7.51 | sweet | 1.5 |
| 9.86 | plastic | 1 | 10.76 | baked | 2 | 8.10 | sulfurous | 2 |
| 10.00 | waxy | 1 | 10.76 | earthy | 2.5 | 8.21 | earthy | 1.5 |
| 10.34 | sweet cream | 1 | 10.76 | coffee | 1 | 8.24 | sulfurous/metallic | 3 |
| 10.48 | roasted/meaty | 1 | 11.20 | cooked | 1 | 8.36 | mushrooms | 1.5 |
| 10.73 | earthy | 1 | 11.21 | baked | 1 | 8.42 | chemically | 3 |
| 10.74 | roasted/burnt | 2 | 12.22 | dirt | 1 | 8.46 | plastic | 2 |
| 10.76 | chocolate/burnt | 1 | 12.24 | earthy | 1 | 10.21 | roasted | 1 |
| 11.21 | dirt | 1 | 12.85 | grape | 1 | 10.51 | earthy/woody | 3 |

| | |
|---|---|
| 11.21 phenolic | 1 |
| 11.53 phenolic | 1 |
| 12.20 peanutty | 2 |
| 12.20 cabbage | 1 |
| 12.21 earthy | 1 |
| 12.43 phenolic | 1 |
| 13.63 plastic | 1 |
| 15.52 roasted | 1 |
| 15.60 cinnamon | 2 |
| 16.03 phenolic | 1 |
| 16.39 raw peanut | 1 |
| 16.56 burnt/medicinal | 2 |
| 17.58 earthy | 1 |
| 18.52 sweet/feed | 1 |
| 18.75 roasted/burnt | 1 |

| | |
|---|---|
| 13.47 musty/burnt | 1 |
| 13.50 powder drink | 1 |
| 13.91 clothes dryer | 1 |
| 13.96 floral | 1 |
| 15.71 putrid/rancid | 1 |
| 16.80 plastic | 1 |
| 17.91 plastic | 1 |
| 18.01 floral | 1 |
| 19.48 earthy | 1 |

| | |
|---|---|
| 10.67 plastic | 1.5 |
| 10.73 baked | 2 |
| 10.85 coffee | 3 |
| 10.96 nutty | 3 |
| 11.12 grainy/roasted | 1.5 |
| 11.60 sweet | 2 |
| 11.93 earthy | 1.5 |
| 12.00 earthy | 2 |
| 12.08 sweet | 1 |
| 12.10 green | 1.5 |
| 12.18 floral | 1 |
| 12.23 baked/roasted | 2 |
| 12.61 roasted | 1 |
| 13.11 sweet/caramel | 1 |
| 14.18 roasted | 1 |
| 14.21 green | 1 |
| 14.74 sweet/floral | 1 |
| 15.27 baked | 1 |
| 16.21 baked | 1 |
| 16.92 plastic | 1 |
| 18.26 moldy | 1 |
| 18.78 roasted | 1 |
| 19.76 sweet/chemically | 1 |

Rep 1 Treament 3 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 2.00 | phenolic | 1 |
| 2.10 | plastic | 1 |
| 2.64 | acetic acid | 1 |
| 2.69 | roasted | 2 |
| 2.71 | feed | 1.5 |
| 2.85 | baked | 1 |
| 4.36 | phenolic | 2 |
| 4.40 | cheesy | 3 |
| 4.46 | cheesy | 1 |
| 4.53 | cheesy/rancid | 3 |
| 4.54 | old tennis shoes/rancid | 1 |
| 4.76 | rancid | 1 |
| 4.90 | plastic | 1 |
| 5.40 | stinky feet | 3 |
| 5.49 | musty/stinky feet | 2 |
| 5.49 | cheesy | 2 |
| 6.11 | nutty/roasted | 2 |
| 6.12 | baked | 1 |
| 6.70 | medicinal | 2 |
| 6.83 | vitamins | 2.5 |
| 6.84 | roasted | 3 |
| 6.85 | potato chip | 2 |
| 6.91 | vitamins/roasted | 2.5 |
| 7.98 | burnt/plasticy | 1 |
| 8.37 | cooked vegetable/garlic | 1 |
| 8.42 | plastic | 3 |
| 8.46 | mushrooms | 1 |
| 8.50 | vegetable | 1 |
| 8.56 | plastic | 2 |
| 9.31 | plastic | 2 |
| 10.24 | earthy/mushrooms | 1 |
| 10.75 | earthy/moldy | 1 |
| 11.09 | peanut brittle | 1 |
| 11.63 | grain/feed | 1 |
| 11.76 | fruity/malty | 1 |
| 12.21 | grassy/roasted | 2 |
| 12.24 | earthy | 1 |
| 12.25 | dirt/earthy | 1 |
| 12.44 | fruity | 1 |
| 12.71 | roasted | 1 |
| 13.50 | earthy/moldy | 1 |
| 14.10 | earthy/mushrooms | 1 |
| 15.17 | grape | 1 |
| 15.70 | metallic | 1 |

Rep 2 Treatment 3 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 1.42 | plastic | 1 |
| 2.01 | earthy | 1 |
| 2.26 | acidic/sour | 2 |
| 2.38 | acetic acid | 2 |
| 2.45 | acetic acid | 1 |
| 2.57 | nutty | 2 |
| 2.65 | grain/feed | 1.5 |
| 2.68 | roasted | 1 |
| 2.69 | pungent | 1 |
| 2.82 | roasted | 1 |
| 2.87 | floral | 1 |
| 2.98 | plastic | 1.5 |
| 3.27 | baked | 1 |
| 3.29 | plastic | 1 |
| 4.42 | cheesy | 3 |
| 4.47 | cheesy | 1.5 |
| 4.55 | grassy/floral | 2 |
| 4.58 | roasted | 1 |
| 4.72 | phenolic/chemically | 1 |
| 5.38 | burnt/chemically | 1 |
| 5.39 | sweaty/pungent | 2 |
| 5.49 | musty | 1.5 |
| 5.52 | rancid | 1 |
| 5.59 | musty | 2 |
| 5.79 | floral | 1 |
| 5.94 | baked | 1 |
| 6.07 | roasted | 1 |
| 6.11 | baked | 1 |
| 6.56 | poultry | 1 |
| 6.66 | chromium picolinate | 2 |
| 6.75 | baked/cereal | 2 |
| 6.80 | vitamins | 2 |
| 6.85 | roasted | 2 |
| 6.98 | plastic | 1 |
| 7.06 | nutty | 1 |
| 8.16 | sulfurous | 1 |
| 8.26 | metallic | 2 |
| 8.40 | sulfurous/metallic | 3 |
| 8.44 | plastic | 1 |
| 8.44 | mushrooms | 1.5 |
| 8.51 | plastic | 2 |
| 8.56 | burnt plastic | 2 |
| 8.94 | floral | 1 |
| 9.96 | floral | 1.5 |

Rep 3 Treatment 3 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 1.13 | plastic | 1 |
| 1.73 | sweet | 1 |
| 2.20 | sour/acidic | 1 |
| 2.27 | plastic | 1 |
| 2.30 | acetic acid | 2.5 |
| 2.46 | acetic acid | 1 |
| 2.58 | putrid/rancid | 3 |
| 2.61 | roasted grain | 2.5 |
| 2.65 | roasted | 2 |
| 2.74 | musty | 2 |
| 2.99 | plastic | 1 |
| 4.36 | cheesy | 1 |
| 4.38 | cheesy | 1 |
| 4.41 | cheesy/rancid | 2.5 |
| 4.63 | green/grassy | 1 |
| 4.67 | musty | 1 |
| 5.36 | musty | 1 |
| 5.42 | musty/stinky feet | 1 |
| 5.46 | cheesy/rancid | 3 |
| 5.46 | roasted | 1 |
| 5.69 | plastic | 1 |
| 6.61 | roasted | 1 |
| 6.65 | chromium picolinate | 3 |
| 6.67 | sweet/medicinal | 3 |
| 6.72 | roasted/vitamins | 3 |
| 6.80 | medicinal/sweet | 3 |
| 7.02 | nutty/baked | 1 |
| 7.19 | burnt/chemically | 2 |
| 7.63 | grassy | 1 |
| 7.84 | sulfurous | 2 |
| 8.25 | metallic | 2 |
| 8.30 | roasted/rubbery | 1 |
| 8.34 | mushrooms | 1 |
| 8.39 | sulfurous/metallic | 2 |
| 8.42 | plastic | 2.5 |
| 8.48 | rubbery/chemically | 2.5 |
| 8.79 | medicinal | 1 |
| 9.42 | earthy/moldy | 1 |
| 10.29 | baked | 1 |
| 10.58 | coffee/earthy | 2 |
| 10.64 | roasted grain | 1.5 |
| 10.95 | sweet | 1 |
| 11.16 | baked | 1 |
| 12.03 | earthy/woody | 1 |

| | |
|---|---|
| 16.44 musty | 1 |
| 16.78 grain/feed | 1 |
| 17.38 cooked | 1 |

| | |
|---|---|
| 9.96 earthy | 1 |
| 10.62 earthy/woody | 1 |
| 10.75 earthy | 1 |
| 10.76 sweet | 1 |
| 10.78 nutty/baked | 1 |
| 10.90 floral | 1 |
| 10.96 sweet/caramel | 2 |
| 11.12 medicinal | 1 |
| 11.35 sweet | 1 |
| 12.09 earthy/dirt | 1 |
| 12.22 fishy | 1 |
| 12.24 baked | 1 |
| 12.30 sweet/malty | 1 |
| 12.54 nutty | 1 |
| 12.74 baked | 1 |
| 15.05 grapes/fruity | 1 |
| 15.18 grape | 1.5 |
| 15.24 anise | 1 |
| 15.50 floral | 1 |
| 15.55 cinnamon | 1 |
| 15.55 floral | 1 |
| 17.92 plastic | 1 |
| 19.44 baked cookies | 1 |

| | |
|---|---|
| 12.10 medicinal | 1.5 |
| 12.20 musty | 1 |
| 12.25 sweet | 1 |
| 14.94 earthy/mushrooms | 1 |
| 15.06 grape | 1 |
| 16.36 grainy | 1 |
| 17.23 plastic | 1 |
| 18.40 plastic | 1 |

| Rep 1 Treatment 4 Ambient | | Rep 2 Treatment 4 Ambient | | Rep 3 Treatment 4 Ambient | |
|---|---|---|---|---|---|
| Rt | Aroma | Rt | Aroma | Rt | Aroma |
| 1.19 | phenolic | 0.58 | plastic | 1.65 | musty |
| 1.29 | roasted | 1.34 | musty | 1.74 | meaty |
| 1.61 | earthy | 1.84 | old tennis shoes | 1.77 | roasted |
| 1.66 | chocolate | 1.99 | cooked | 2.23 | acetic acid |
| 1.70 | cooked | 2.34 | acidic/sour | 2.29 | acetic acid |
| 1.81 | earthy | 2.43 | musty | 2.49 | roasted |
| 1.90 | sour/stinky | 2.59 | pungent | 2.59 | chemically/roasted |
| 2.40 | urine-like | 2.64 | roasted grain | 2.59 | putrid |
| 2.43 | phenolic | 2.70 | roasted | 2.68 | musty |
| 2.69 | roasted | 2.74 | sweaty/stinky | 2.68 | plastic |
| 2.71 | grainy | 3.99 | plastic | 4.36 | cheesy/rancid |
| 2.81 | plastic | 4.47 | cheesy | 4.39 | cheesy/rancid |
| 3.13 | roasted | 4.48 | cheesy | 4.46 | chemically |
| 3.46 | plastic | 4.59 | grassy/floral | 4.52 | green |
| 4.26 | medicinal/plasticy | 4.67 | green/grassy | 4.53 | grassy |
| 4.40 | stinky feet | 5.45 | meaty/stinky feet | 5.31 | musty |
| 4.47 | cheesy/rancid | 5.45 | moldy/musty | 5.37 | rancid/cheesy |
| 4.48 | rancid/cheesy | 5.59 | musty | 6.54 | poultry |
| 4.73 | green/grassy | 5.98 | baked | 6.62 | sour |
| 5.43 | musty/stinky feet | 6.08 | sweet | 6.65 | chromium picolinate |
| 5.46 | stinky feet | 6.54 | roasted meat | 6.71 | roasted/vitamins |
| 5.48 | cheesy/rancid | 6.60 | poultry | 6.75 | roasted |
| 5.86 | phenolic | 6.72 | chromium picolinate | 7.02 | nutty |
| 6.08 | roasted | 6.73 | musty | 7.13 | fritos |
| 6.11 | nutty | 6.80 | vitamins | 7.16 | burnt |
| 6.17 | roasted | 6.86 | roasted | 7.41 | sweet |
| 6.57 | baked | 7.09 | nutty/roasted | 7.51 | sweet |
| 6.71 | baked meat | 7.20 | baked/cereal | 8.25 | sulfurous/metallic |
| 6.80 | vitamins | 8.21 | sulfurous/onion | 8.27 | baked |
| 6.85 | roasted | 8.37 | metallic | 8.34 | mushrooms |
| 6.86 | potato chip | 8.41 | mushrooms | 8.35 | metallic |
| 7.17 | medicinal/phenolic | 8.48 | metallic/sulfurous | 8.40 | chemically |
| 7.23 | fritos | 8.51 | plastic | 8.45 | plastic |
| 7.23 | cereal | 8.58 | plasticy/rubbery | 9.59 | meaty/oily |
| 7.78 | plastic | 8.88 | fruity | 10.58 | earthy/woody |
| 8.12 | root/grass | 9.65 | oily | 10.69 | earthy |
| 8.46 | mushrooms | 10.11 | sweet/floral | 10.71 | nutty/roasted |
| 8.49 | old | 10.49 | roasted | 11.00 | sweet/baked |
| 8.53 | burnt/roasted | 10.64 | coffee/dirt | 11.08 | roasted grain |
| 8.56 | plastic | 10.76 | earthy/mushrooms | 11.78 | earthy |
| 8.60 | moldy | 11.00 | sweet | 12.02 | earthy/ethereal |
| 9.32 | urine | 11.10 | nutty | 12.14 | musty |
| 9.78 | oily | 11.19 | creamy | 12.15 | plastic |
| 10.50 | sweet | 11.20 | plasticy | 12.23 | mushrooms |
| 10.62 | sweet | 11.25 | sweet | 12.62 | burnt |
| 10.72 | earthy/moldy | 11.34 | baked cookie | 12.84 | earthy |
| 10.75 | burnt/roasted | 12.10 | earthy/woody | 13.60 | plastic |

| Rep 1 Treatment 4 Ambient | | Rep 2 Treatment 4 Ambient | | Rep 3 Treatment 4 Ambient | |
|---|---|---|---|---|---|
| Level | | Level | | Level | |
| 1 | | 1 | | 1 | |
| 1 | | 2 | | 1.5 | |
| 2 | | 1 | | 1 | |
| 1 | | 1 | | 2.5 | |
| 1 | | 1 | | 1 | |
| 2 | | 1 | | 2 | |
| 1 | | 2 | | 2 | |
| 1 | | 1 | | 3 | |
| 1 | | 2 | | 2 | |
| 2.5 | | 1 | | 1 | |
| 2 | | 1.5 | | 3 | |
| 2 | | 1 | | 2 | |
| 2 | | 1 | | 1 | |
| 1 | | 1 | | 1 | |
| 1 | | 2 | | 2 | |
| 2 | | 2 | | 1 | |
| 2 | | 1 | | 2 | |
| 1 | | 1 | | 1.5 | |
| 2.5 | | 1 | | 2 | |
| 2 | | 1 | | 3 | |
| 2 | | 1 | | 2.5 | |
| 1 | | 1 | | 3 | |
| 2 | | 2 | | 2 | |
| 2 | | 2 | | 2.5 | |
| 2 | | 2 | | 1 | |
| 2 | | 2 | | 1 | |
| 2.5 | | 2 | | 1.5 | |
| 3 | | 2 | | 2 | |
| 2.5 | | 1 | | 1 | |
| 3 | | 2 | | 2 | |
| 3 | | 3 | | 2 | |
| 2 | | 3 | | 1 | |
| 1 | | 1 | | 2 | |
| 3 | | 2 | | 2 | |
| 1 | | 1 | | 1 | |
| 3 | | 1.5 | | 1 | |
| 2.5 | | 2 | | 1 | |
| 1 | | 1 | | 2 | |
| 1 | | 1 | | 1 | |
| 1 | | 1 | | 1 | |
| 1 | | 1 | | 1 | |
| 1 | | 1 | | 1 | |
| 2 | | 1 | | 2 | |
| 1.5 | | 1.5 | | 1 | |
| 1 | | 1 | | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| 10.78dirt | 1 | 12.22earthy | 1 | 14.42chemically | 2 |
| 11.24roasted | 1 | 12.26burnt | 1 | 15.29earthy | 1 |
| 12.11egg | 1 | 12.32sweet/malty | 1 | 16.15grapes/fruity | 1 |
| 12.17toasted grain | 1 | 13.81burnt | 1 | 17.19roasted | 1 |
| 12.21phenolic | 1 | 15.29graham crackers | 1 | 18.67chemically | 2 |
| 12.29dirt | 1 | 15.50sweet | 1 | | |
| 12.64urine | 1 | 15.69grapes | 1 | | |
| 12.85earthy/mushrooms | 1 | 16.08burnt | 1 | | |
| 13.79urine-like | 1 | 16.59grassy/floral | 1 | | |
| 14.12urine-like | 1 | 17.44plastic | 1 | | |
| 15.15medicinal | 1 | 17.94woody/earthy | 1 | | |
| 15.20grape | 1 | 19.15feed/grain | 1 | | |
| 15.39stink bug | 1 | | | | |
| 15.59moldy/woody | 2 | | | | |
| 15.70cinnamon | 1 | | | | |
| 16.58dirt/earthy | 1 | | | | |
| 16.86floral | 1 | | | | |
| 18.40cooked | 1 | | | | |

| Rep 1 Treatment 5 Ambient | | | Rep 2 Treatment 5 Ambient | | | Rep 3 Treatment 5 Ambient | | |
|---|---|---|---|---|---|---|---|---|
| Rt | Aroma | Level | Rt | Aroma | Level | Rt | Aroma | Level |
| 1.61 | medicinal | 1 | 2.26 | acetic acid/sour | 1 | 0.53 | burnt | 1 |
| 1.81 | earthy | 1 | 2.41 | grassy | 1 | 1.04 | plastic | 1 |
| 2.05 | cheesy | 1 | 2.44 | musty | 1 | 1.78 | earthy | 1 |
| 2.10 | sour | 1 | 2.55 | pungent | 2 | 1.96 | butterscotch/sweet | 1 |
| 2.27 | acetic acid | 1 | 2.58 | roasted | 2 | 2.30 | acetic acid | 2 |
| 2.53 | pungent | 1 | 2.66 | roasted | 1 | 2.39 | acidic/sour | 1 |
| 2.63 | musty | 1 | 2.69 | gassy | 1 | 2.58 | putrid/stinky | 3 |
| 2.65 | sulfurous | 1 | 3.11 | phenolic | 1 | 2.63 | baked | 2 |
| 3.91 | burnt | 1 | 4.39 | roasted/baked | 1 | 2.68 | grainy/feed | 1 |
| 4.24 | cheesy | 1 | 4.46 | cheesy | 1 | 2.72 | baked/roasted | 1 |
| 4.25 | plastic | 1 | 4.57 | grassy/floral | 1 | 3.04 | baked | 1 |
| 4.34 | rancid | 2 | 4.68 | green/grassy | 1 | 3.17 | phenolic/rubbery | 2 |
| 4.39 | earthy/moldy | 2 | 4.72 | bubble gum | 1 | 3.49 | plastic | 1 |
| 4.47 | cheesy | 1 | 4.93 | plastic | 1 | 3.76 | sweet cream | 1 |
| 4.47 | grassy | 1 | 5.46 | earthy/mushrooms | 1 | 4.39 | cheesy | 1 |
| 4.53 | medicinal/chemical | 1 | 5.56 | musty | 2 | 4.52 | cheesy | 1 |
| 4.76 | grassy | 1 | 5.62 | plastic | 2.5 | 4.55 | grassy | 1 |
| 5.26 | rancid/grassy | 3 | 6.60 | baked | 1 | 4.60 | medicinal | 1 |
| 5.39 | musty/stinky feet | 1.5 | 6.78 | vitamins | 2.5 | 4.62 | roasted grain | 1 |
| 5.48 | musty | 2 | 6.80 | baked/roasted | 1 | 5.16 | sweet cream | 1 |
| 5.51 | dirt/stinky | 1 | 6.91 | sweet | 1.5 | 5.35 | rancid | 1 |
| 6.28 | phenolic | 1 | 7.07 | phenolic | 1.5 | 5.40 | medicinal/phenolic | 1 |
| 6.44 | roasted | 1 | 7.10 | nutty | 2 | 5.48 | musty | 1 |
| 6.59 | chromium picolinate | 2 | 7.21 | fritos | 1.5 | 5.52 | cheesy/rancid | 2 |
| 6.81 | vitamins | 3 | 8.15 | floral | 2 | 5.53 | musty | 1 |
| 6.86 | potato chip | 2 | 8.20 | sulfurous | 1 | 5.71 | rancid/pungent | 2 |
| 6.98 | nutty | 2 | 8.34 | sulfurous/metallic | 2 | 6.16 | roasted | 1 |
| 7.21 | fritos | 2.5 | 8.45 | mushrooms | 1.5 | 6.67 | chromium picolinate | 1 |
| 7.60 | medicinal | 2 | 8.47 | metallic | 3 | 6.67 | spicy/acidic | 3 |
| 7.77 | medicinal | 1.5 | 8.51 | plastic | 1 | 6.79 | roasted | 3 |
| 7.85 | sweet/caramel | 2 | 8.53 | plastic | 2 | 6.82 | vitamins | 1.5 |
| 7.94 | plastic | 3 | 10.09 | sweet | 1 | 7.20 | fritos | 1 |
| 8.05 | sulfurous | 1 | 10.56 | baked | 1 | 8.27 | sulfurous | 2 |
| 8.18 | sulfurous/metallic | 3 | 10.66 | coffee/dirt | 3 | 8.39 | sulfurous/metallic | 2 |
| 8.42 | mushrooms | 2.5 | 10.75 | earthy/woody | 1 | 8.42 | phenolic | 2 |
| 8.51 | dirt/plant | 1 | 10.79 | roasted | 1 | 8.43 | mushrooms | 2 |
| 8.53 | plastic | 2.5 | 11.04 | sweet | 2 | 8.52 | chemically | 3 |
| 9.74 | sweet/baked | 1.5 | 11.19 | cereal/baked | 1 | 8.78 | roasted | 1 |
| 9.82 | phenolic | 1 | 11.22 | floral | 1 | 8.92 | lemon/citus | 2 |
| 10.05 | sweet/baked | 1 | 12.14 | earthy/woody | 1 | 9.60 | musty | 1 |
| 10.08 | earthy | 1 | 12.18 | sweet | 1 | 10.22 | baked/cookies | 1 |
| 10.26 | hexanal | 1 | 12.26 | burnt | 1 | 10.75 | earthy | 1 |
| 10.28 | sweet/woody | 2 | 12.34 | sweet | 1 | 10.78 | roasted/meaty | 1 |
| 10.50 | coffee | 1 | 12.69 | earthy | 1 | 11.10 | sweet/baked | 1 |
| 10.58 | cooked vegetable | 1 | 14.29 | plastic | 1 | 11.21 | baked | 1.5 |
| 10.79 | phenolic | 1 | 15.29 | grapes | 1 | 12.10 | earthy | 1 |
| 10.80 | cooked vegetable | 1 | 15.56 | anise | 1 | 12.22 | baked/roasted | 1 |

| | |
|---|---|
| 10.88sweet | 1 |
| 10.95sweet/nutty | 1 |
| 11.27sulfurous | 1 |
| 11.36phenolic | 1 |
| 11.81plastic | 1 |
| 11.95earthy | 1 |
| 12.26grain/planty | 1 |
| 12.27mushrooms/earthy | 1 |
| 12.54floral | 1 |
| 13.58floral | 1 |
| 13.83honey | 1 |
| 14.36phenolic | 1 |
| 15.09leafy | 1 |
| 15.18grapes | 1 |
| 15.42stink bug | 1 |
| 15.55burnt | 2 |
| 16.15fruity | 1 |
| 17.97floral | 1 |

| | |
|---|---|
| 15.66cinnamon | 1 |
| 15.68floral | 1 |
| 16.77burnt | |

| | |
|---|---|
| 12.45rubbery/chemically | 2 |
| 13.22plastic | 1.5 |
| 13.64rubbery/chemically | 2 |
| 13.97earthy | 1 |
| 15.07grape | 1 |
| 15.19grape/floral | 1.5 |
| 17.34baked | 1 |
| 18.08plastic | 1 |
| 18.34burnt | 1 |
| 18.71burnt | 1 |
| 19.05earthy/mushrooms | 1 |
| 19.68baked | 1 |

Rep 1 Treatment 6 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 1.15 | urine-like | 1 |
| 1.39 | sweet | 1 |
| 2.20 | acid | 1 |
| 2.26 | sour | 1 |
| 2.51 | pungent/rancid | 1 |
| 2.60 | sweet/candy | 1 |
| 2.62 | urine-like | 1 |
| 3.37 | roasted | 1 |
| 3.96 | urine-like | 1 |
| 4.25 | mushrooms | 1 |
| 4.27 | cheesy | 1 |
| 4.46 | grassy | 2 |
| 4.49 | cheesy | 1 |
| 4.49 | cheesy | 3 |
| 4.68 | ketones | 1 |
| 5.08 | earthy | 1 |
| 5.44 | musty/stinky feet | 2.5 |
| 5.50 | stinky feet | 2 |
| 6.01 | ketones | 1 |
| 6.49 | boiled poultry | 1 |
| 6.57 | chromium picolinate | 2 |
| 6.81 | vitamins | 2.5 |
| 6.88 | potato chip | 3 |
| 6.94 | nutty | 1 |
| 7.25 | fritos | 1.5 |
| 7.88 | grape/fart | 2 |
| 8.05 | sulfurous | 1 |
| 8.16 | sulfurous/metallic | 2 |
| 8.33 | sulfurous/metallic | 3 |
| 8.43 | mushrooms | 2.5 |
| 8.54 | musty | 1 |
| 8.58 | plastic | 1 |
| 8.62 | baked | 1 |
| 10.47 | coffee/earthy | 2 |
| 10.79 | roasted grain | 1 |
| 10.84 | sweet | 1 |
| 10.93 | sweet/nutty | 1 |
| 11.11 | phenolic | 1 |
| 11.23 | phenolic | 1.5 |
| 11.23 | urine-like | 1 |
| 11.70 | celery | 1 |
| 11.98 | earthy | 1 |
| 12.19 | phenolic | 1 |
| 12.25 | roasted | 1.5 |
| 12.31 | dirt | 1 |
| 12.54 | urine-like | 1 |
| 12.90 | medicinal | 1 |

Rep 2 Treatment 6 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 1.84 | earthy/mushrooms | 1 |
| 2.54 | plastic | 1 |
| 2.62 | roasted | 2 |
| 2.69 | roasted | 1 |
| 2.74 | roasted | 2 |
| 4.40 | rancid | 1 |
| 4.45 | cheesy | 1 |
| 4.80 | floral | 1 |
| 5.19 | baked | 1 |
| 5.49 | musty | 1 |
| 6.09 | peanuts | 1 |
| 6.77 | vitamins | 2 |
| 6.78 | roasted | 2 |
| 6.82 | potato chip | 3 |
| 7.08 | onion | 1 |
| 7.21 | roasted | 1 |
| 7.22 | creamy | 1 |
| 7.59 | floral | 1 |
| 8.40 | mushrooms | 1 |
| 8.44 | musty | 3 |
| 8.49 | rooty | 1 |
| 8.54 | burnt | 3 |
| 8.59 | plastic | 1 |
| 10.76 | earthy/woody | 1 |
| 11.26 | grass | 1 |
| 11.37 | sweet | 1 |
| 11.92 | burnt/plasticy | 1 |
| 12.08 | plastic | 1 |
| 12.22 | medicinal | 1 |
| 12.28 | dirt | 2 |
| 12.46 | plastic | 1 |
| 13.76 | cheesy | 1 |
| 14.28 | banana/fruity | 1 |
| 15.39 | stink bug | 1 |
| 15.81 | fruity | 1 |
| 17.74 | clothes dryer | 1 |
| 17.81 | phenolic | 1 |
| 17.92 | earthy/rooty | |

Rep 3 Treatment 6 Ambient

| Rt | Aroma | Level |
|---|---|---|
| 1.11 | baked | 1 |
| 1.73 | sweet | 1 |
| 1.79 | earthy/mushrooms | 1.5 |
| 1.83 | musty | 1 |
| 2.50 | plastic | 1 |
| 2.56 | acetic acid | 1 |
| 2.57 | pungent/rancid | 3 |
| 2.70 | grain/roasted | 1 |
| 2.78 | baked | 1 |
| 2.87 | stink bug | 1.5 |
| 3.12 | burnt | 1 |
| 4.36 | cheesy | 2 |
| 4.44 | cheesy | 2 |
| 4.51 | grassy | 3 |
| 4.58 | musty | 1 |
| 4.68 | stinky | 1 |
| 4.98 | baked | 1 |
| 5.44 | musty/stinky feet | 2 |
| 5.47 | rancid/cheesy | 3 |
| 6.08 | sweet cream | 3 |
| 6.62 | chromium picolinate | 1 |
| 6.69 | nutty/medicinal | 3 |
| 6.78 | vitamins | 2.5 |
| 6.80 | roasted | 3 |
| 7.02 | nutty | 1 |
| 7.17 | fritos | 2.5 |
| 7.30 | sweet | 1 |
| 8.29 | sulfurous | 2 |
| 8.39 | mushrooms | 2.5 |
| 8.50 | burnt/chemically | 2 |
| 8.59 | sulfurous/metallic | 2 |
| 9.62 | plastic | 1.5 |
| 10.74 | burnt/grain | 1.5 |
| 10.75 | roasted | 2 |
| 11.22 | musty | 1 |
| 11.24 | baked | 1 |
| 11.88 | roasted | 1 |
| 12.04 | earthy | 1 |
| 12.18 | earthy | 1 |
| 12.18 | baked | 2 |
| 12.31 | baked cookies | 1 |
| 12.41 | plasticy | 1 |
| 14.41 | plastic | 1 |
| 15.18 | grape | 1.5 |
| 15.39 | grainy/burnt | 1 |
| 16.18 | roasted | 1 |
| 18.05 | fruity/floral | 2 |

| | | | |
|---|---|---|---|
| 13.89 | sweet | 1 | |
| 14.43 | earthy | 1.5 | |
| 15.16 | grape | 1 | |
| 15.38 | stink bug | 1.5 | |
| 15.62 | fruity | 1 | |
| 15.89 | leafy | 1 | |
| 16.97 | woody | 1 | |
| 17.47 | earthy | 1 | |
| 19.61 | roasted | 1 | |

# VITAE

Donna Mechelle Greene was born in Morristown, Tennessee where she graduated from Morristown West High School. Following graduation, she attended Walters State Community College for two years and then went to University of Tennessee, Knoxville receiving her Bachelor's degree in Agriculture with a major of Food Science in 2002.

Following graduation, Donna came to Virginia Tech to work on her Master's degree in Food Science and Technology. She began her program in the Fall of 2002. She was a member of the Institute of Food Technologist (IFT) and Poultry Science Association (PSA). Donna was also a member of the Food Science club while at Virginia Tech. While at Virginia Tech Donna helped to train the Dairy Product Evaluation Collegiate Team.

Donna is the first generation to attend college in her family and the first person in her family to receive a Master's degree.