Effect of dietary fat source and exercise on odorant-detecting ability of canine athletes

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Abstract

Eighteen male English Pointers (2–4 years of age, 23.94 ± 0.54 kg body weight) were allotted to three diet and two physical conditioning groups to evaluate the effect of level and source of dietary fat on the olfactory acuity of canine athletes subjected to treadmill exercise. Diet groups (6 dogs/diet) consisted of commercially prepared diets (minimum of 26% crude protein) containing 12% fat as beef tallow (A), 16% fat provided by equivalent amounts of beef tallow and corn oil (B), or 16% fat provided by equivalent amounts of beef tallow and coconut oil (C). This dietary formulation resulted in approximately 60% of the total fatty acid being saturated for diets A and C, while approximately 72% of the total fatty acids were unsaturated in diet B. One-half of the dogs within each dietary group were subjected to treadmill exercise 3 times per week for 30 min (8.05 km/h, 0% grade) for 12 weeks. All dogs were subjected to a submaximal exercise stress test (8.05 km/h, 10% slope for 60 min) every four weeks beginning at week 0. Olfactory acuity was measured utilizing behavioral olfactometry before and after each physical stress test. Non-conditioned (NON) dogs displayed a greater decrease ($P < 0.05$) in olfactory acuity following exercise, while physically conditioned (EXE) dogs did not show a change from pre-test values. A diet by treatment interaction ($P < 0.10$) was detected over the course of the study. NON dogs fed coconut oil had decreased odorant-detecting capabilities when week 4 values were compared with week 12 values. Feeding a diet that is predominately high in saturated fat may affect the odorant-detecting capabilities of working dogs. Additionally, these data indicate that utilization of a moderate physical conditioning program can assist canine athletes in maintaining olfactory acuity during periods of intense exercise.
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Keywords: Dietary fat; Canine; Athlete; Odorant; Exercise; Olfaction; Fatty acid; Behavioral olfactometry

1. Introduction

Acceptable performance of many working canines is highly dependent on the olfactory acuity of the animal. Currently, working canines provide a variety of services to our society including the detection of narcotics, explosives, and other contraband. Additionally, these canine athletes are utilized in outdoor sporting events such as hunting and field trial competitions (Holloway, 1961). Olfactory acuity is measured as the lowest concentration of a selected odorant that can be detected by an or-

ganism. The olfactory acuity of dogs is exceptional based on their ability to detect compounds that range in concentrations from 10^{-16} to 10^{-18} M/L (Moulton and Marshall, 1981; Myers, 1991a). Although limited research is available, conditions such as canine distemper (Myers et al., 1988a) and canine parainfluenza virus infections (Myers et al., 1988b) may alter canine olfactory acuity. Other clinical trials suggest that olfactory sensitivity may be affected by hypothyroidism, seizure disorders, diabetes mellitus and head trauma (Myers, 1991b).

Trainers have traditionally utilized high carbohydrate diets in an effort to maintain acceptable performance of canine athletes. This practice is based on reports of enhanced levels of performance when humans athletes consume high carbohydrate diets (Brotherhood, 1984;

Coyle, 1992). In contrast, research using canine athletes has shown several beneficial effects of feeding increased dietary fat on physical performance. Dietary fat during exercise spares blood glucose and muscle glycogen reserves (Kronfeld et al., 1994). Reynolds et al. (1995) reported that trained sled dogs fed high fat diets relied less on glucose oxidation to maintain intense physical activity compared with sled dogs fed a high carbohydrate diet, and were able to sustain the intensity level of physical activity for a longer period of time. While increased dietary fat is a proven performance enhancing tool in canine athletes, it is not known whether the dietary fat level and (or) dietary fatty acid composition affects olfactory acuity and odorant-detecting capabilities of dogs.

Clandinin et al. (1985) reported that fatty acid content of the intestinal mucosa and adipose tissue was altered by dietary fat consumption. Foot et al. (1983) indicated that nutritionally adequate diets containing various dietary fat sources altered the fatty acid content and composition of lipids in the brain. Changes in neurocellular membranes can alter the activity of lipid-dependent enzymes required for neurotransmission (Gerbi et al., 1994, 1993). Therefore, it is plausible that altering the ratio of dietary saturated and unsaturated fatty acids will alter the fatty acid composition of the nasal epithelium of canine athletes resulting in altered olfactory function. This hypothesis is based on research that indicates different sources of dietary fat alter the fatty acid composition and functionality of various cellular membranes (Campbell and Dorn, 1992; Periago et al., 1990; Sebokva et al., 1990). No experiments have been published that have evaluated the effects of dietary components on the odorant-detecting capabilities of canine athletes. Therefore, the objective of this study was to investigate the effects of dietary fat (source and level) and physical conditioning on the olfactory acuity of canine athletes subjected to treadmill exercise.

2. Materials and methods

2.1. Animals

Eighteen healthy, performance bred, male pointers (2–4 years of age, 23.94 ± 0.54 kg body weight) were selected from kennels from across the Southeast region of the United States. All dogs received complete physical examinations by the project clinician and were pronounced to be in normal health prior to entering the study. No dog had received regular physical conditioning or field training for at least 6 months prior to initiation of the study. Dogs were housed individually in USDA approved kennel facilities located at the Auburn University College of Veterinary Medicine campus for the duration of the study. All procedures were pre-ap-

proved by the Institute Animal Care and Use Committee for Auburn University and were in accordance with the Guide for the Care and Use of Laboratory Animals (National Research Council, 1996). All dogs successfully completed this study.

2.2. Diets and feeding regimes

The term "diet" refers to the formulation of the feed presented to each dog during the study. All dogs were given free access to fresh water and fed a complete and balanced dry diet (Diet A, control) containing a minimum of 26% crude protein and 12% crude fat (comprised of beef tallow), during a four week acclimation period prior to the initiation of the study. This control diet formulation was selected for this study because a similar diet was being commercially marketed as an appropriate diet for adult athletic dogs.

For the experiment, dogs were allotted to one of the three diet groups (6 dogs/diet group). The diets were formulated based on Association of American Feed Control Officials nutrient requirements for adult dogs

Table 1
Diet formulas[a]

Ingredient[b] (as-fed)	Diet A[c] (control)	Diet B[d] (unsaturated)	Diet C[e] (saturated)
Ground yellow corn	36.0	29.1	29.1
Soybean meal	15.4	17.8	17.8
Corn gluten meal	13.5	16.0	16.0
Rice bran	11.0	11.0	11.0
Beef tallow	8.0	4.0	4.0
Corn oil	—	8.0	—
Coconut oil	—	—	8.0
Beef and bone meal	6.5	2.0	2.0
Wheat	6.0	6.0	6.0
Brewers yeast	1.0	1.0	1.0
Dog vitamin pre-mix	0.7	0.7	0.7
Salt	0.6	0.7	0.7
Dicalcium phosphate	0.5	1.6	1.6
Calcium carbonate	0.3	1.1	1.1
Trace mineral pre-mix	0.2	0.2	0.2
Lysine	0.2	0.2	0.2
Potassium	0.1	0.1	0.1
Choline	0.05	0.05	0.05

[a] Manufactured by Ralston–Purina, St. Louis, MO.
[b] Values reported as percentage of total diet mixture.
[c] Diet A (control): 12% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).
[d] Diet B (unsaturated): 16% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow and 4% corn oil added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).
[e] Diet C (saturated): 16% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow and 4% coconut oil added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).

Table 2
Composition analysis of test diets[a]

Dietary component (as-fed)	Diet A (control)	Diet B (unsaturated)	Diet C (saturated)
Digestible energy (kcal/kg)[b]	4085	4322	4321
Moisture (%)	7.3	5.3	5.0
Protein (%)	26.5	26.6	26.0
NFE (%)	46.1	42.5	42.5
Fat (%)	12.6	16.9	16.8
Fiber (%)	1.3	1.3	1.3
Ash (%)	5.8	6.4	6.4
Calcium (%)	1.0	1.0	1.0
Phosphorus (%)	0.8	0.8	0.8
Sodium (%)	0.3	0.3	0.3
Potassium (%)	0.6	0.6	0.6
Chloride (%)	0.5	0.5	0.5

[a] Manufactured by Ralston–Purina, St. Louis, MO.
[b] Calculated value.

(1996) and fed as an extruded dry product manufactured by Ralston–Purina Company, St. Louis, MO (Tables 1 and 2). Diet B contained a minimum of 26% crude protein and 16% crude fat provided by equal amounts of beef tallow and corn oil. Diet C contained a minimum of 26% crude protein and 16% crude fat provided by equal amounts of beef tallow and coconut oil. Diet formulations resulted in diet B containing predominately unsaturated fatty acids, while diet C contained predominately saturated fatty acids (Table 3). Nutrient composition of each diet was analyzed utilizing the methods approved by the Association of Official Analytical Chemists (16th edition, 1995).

2.3. Physical conditioning program

Dogs from each diet group were allotted to two conditioning groups (physically conditioned and non-conditioned). Physically conditioned dogs (EXE) were exercised three times weekly on a motorized treadmill (Parker Treadmills, Auburn, AL) at a rate of 8.05 km/h (0% slope) for 30 min/day on non-consecutive days. Non-conditioned dogs (NON) were exercised at 8.05 km/h (0% slope) for 10 min/day one day per week to ensure familiarity with the treadmill. Duration of the physical conditioning program was 12 weeks. The physical conditioning program was developed to closely simulate traditional techniques utilized by performance field dog trainers to condition their competitors (Tarrant, 1977; Wehle, 1964).

2.4. Physical stress testing

All dogs were subjected to a submaximal exercise stress test on weeks 0, 4, 8 and 12 of the study. During the two-stage exercise test, dogs were initially exercised at a rate of 8.05 km/h (5% slope) for 15 min, and then at a rate of 8.05 km/h (10% slope) for 45 min. The physical test was concluded at 60 min or when the dog refused to continue.

2.5. Odorants and subject preparation

Olfactory acuity is measured as the lowest concentration of a selected odorant which is detectable by an

Table 3
Fatty acid composition of test diets[a]

Fatty acid[b]		Diet A[c] (control)	Diet B[d] (unsaturated)	Diet C[e] (saturated)
Caprylic	8:0	—	—	2.9
Capric	10:0	—	—	2.5
Lauric	12:0	—	0.3	21.5
Myristic	14:0	1.9	1.0	9.7
Palmitic	16:0	20.8	15.4	14.9
Palmitoleic	16:1	2.1	1.0	1.0
Margaric	17:0	1.0	0.5	0.5
Stearic	18:0	14.2	7.3	7.9
Oleic	18:1	36.5	29.6	21.2
Linoleic	18:2, $n-6$	17.2	40.0	13.9
-Linolenic	18:3, $n-3$	0.9	1.1	0.7
Total saturated fatty acids		37.9	24.5	59.9
Total unsaturated fatty acids		56.8	71.7	36.8
Remaining fatty acids		5.3	3.8	3.3
Omega 6:3		19.1:1	36.4:1	19.9:1

[a] Manufactured by Ralston–Purina, St. Louis, MO.
[b] Values reported as percent of total fat contained in the diet.
[c] Diet A (control): 12% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).
[d] Diet B (unsaturated): 16% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow and 4% corn oil added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).
[e] Diet C (saturated): 16% crude fat (4% beef tallow added internally in diet mixture, 4% beef tallow and 4% coconut oil added externally as a sprayed product following extrusion, and remaining 4% dietary fat derived from basal ingredients).

organism. Olfactory thresholds were determined for all dogs prior to the initiation of this study by behavioral olfactometry utilizing eugenol (Sigma Chemical Company, St. Louis, MO) as the odorant (Ezeh et al., 1992; Myers and Pugh, 1985). Dilutions of ascending concentration of eugenol from 10^{-18} to 10^{-1} M/L of stock solutions of eugenol (6.52 M) in propylene glycol (Fisher Scientific Company, Fair Lawn, NJ) were utilized to determine odorant-detecting thresholds 30 min prior to the treadmill physical stress test and 30 min following the conclusion of the physical stress test. Eugenol was selected as the test odorant based on its ability to stimulate olfactory nerve activity with little or no effect on trigeminal activation (Doty, 1989). One milliliter of each dilution was stored in a separate sealed 12×75 mm borosilicate test tube (Fisher Scientific Company, Fair Lawn, NJ). Odorless blanks were used that contained 1 mL of pure propylene glycol. Care was taken to prevent any cross-contamination of the sample vials.

Subjects were prepared according to previously described techniques for behavioral olfactometry (Ezeh et al., 1992; Myers and Pugh, 1985). Dogs were blindfolded and lightly restrained in a right lateral recumbency and allowed to acclimate for a minimum of 5 min to the environment before the evaluation was initiated. Efforts to create a stimulus-neutral environment (Myers, 1991a) within the testing room included adequate ventilation, temperature control (25 ± 1 °C), white noise to prevent excessive auditory stimulus, and odor control (no perfume, cologne, or smoking allowed, and baking soda bags were utilized as odor absorbents). All dogs were calm prior to odor presentation, as indicated by minimal spontaneous body movement.

2.6. Olfactory function evaluation

Baseline odorant-detecting thresholds for eugenol were established for each dog using triplicate measurements on non-consecutive days using previously described techniques (Ezeh et al., 1992; Myers and Pugh, 1985). The same evaluators performed all olfactory threshold measurements throughout the study. The average of these values was determined to be the baseline odorant-detecting threshold value for each dog. The olfactory acuity for all dogs was determined to be within normal ranges (Myers, 1991b) prior to inclusion in the study. Normal range was determined to be the detection of an odor concentration less than 10^{-9} M/L eugenol (Myers, 1991b).

Each olfactory evaluation test was initiated by presenting the blind-folded dog with the empty test tube holder, a sample blank (pure propylene glycol), and then the individual test tray containing the serial dilution set with three additional blanks randomly placed in the set. The method of presenting the samples was similar to that previously described (Ezeh et al., 1992; Myers and

Pugh, 1985). Each individual sample tube was opened and placed approximately 2 cm ventral to the tip of the dog's nose. Each dilution was presented for 10 s, withdrawn for 15 s, and then followed by the next sample in the serial dilution set. Thresholds for odorant-detection were determined to be the lowest eugenol concentration that evoked an observable, reflexive behavioral response. Behavioral responses were videotaped and analyzed by four observers trained to detect the appropriate behavioral response. A positive olfactory response was determined by the presence of a pre-determined typical behavior pattern of a sniff. Observers independently agreed in every case of response or lack of response to odor stimuli at a given concentration. The 18 tenfold dilutions were recorded as the negative log of the dilution with 1 being the most concentrated and 18 being the least concentrated. A score of 0 was recorded for lack of response. This study was conducted as a double-blind experiment.

2.7. Statistical analysis

Dogs were allotted randomly to diet and conditioning groups. Data were analyzed as a double split plot over time design, with diet, conditioning, week, and time as main effects. The experimental unit was dog within diet and conditioning group. Initial olfactory estimates collected at week 0 were utilized as covariates to assess changes in olfactory acuity during the experimental period. The general linear model (GLM) procedure of SAS (Statistical Analysis Systems Version 6.12, SAS Institute, Cary, NC) was utilized for statistical analyses. Differences among treatment least squares means were separated utilizing the PDIFF option of SAS when protected by a significant ($P < 0.10$) F-test. Initially a complete model, including all three-way interactions, was used to analyze these data. However, three-way interactions that were not significant ($P > 0.10$), as determined by ANCOVA, were eliminated from the final analysis.

3. Results

No differences were detected in baseline olfactory acuity prior to the initiation of the study, and mean acuity (expressed as the negative log of the minimum eugenol concentration needed to elicit a behavioral response) was 16.3 ± 1.2 (SEM). In contrast, physical conditioning affected olfactory acuity ($P < 0.05$) following the one hour of physical stress test with dogs receiving physical conditioning three days per week (EXE) having greater odorant-detecting capabilities compared with NON dogs (Table 4). NON dogs had a 64% reduction in olfactory acuity following the physical stress test based on pre and post-exercise values. However, pre and post-exercise values for EXE dogs were

Table 4
Olfactory acuity of canine athletes pre and post-treadmill exercise[1]

Conditioning[2]	NON	EXE
No. of dogs	9	9
Pre-stress test	10.7 ± 1.3^{ac}	7.8 ± 1.4^{ac}
Post stress test	3.9 ± 1.4^{ad}	8.1 ± 1.2^{bc}
Percent change (%)[3]	−63.6	3.8

[1] LSMeans ± SEM. Values represent the negative log of the minimum eugenol concentration that elicited a behavioral response.

[2] Conditioning: NON, non-conditioned; EXE, physically conditioned.

[3] Percent change in olfactory acuity between pre-stress test values and post stress test values.

[ab] Indicate differences within time period. Means within the same time period lacking a common superscript differ ($P < 0.05$).

[cd] Indicate differences within conditioning group. Means within the same conditioning group lacking a common superscript differ ($P < 0.05$).

similar ($P > 0.10$). NON dogs fed coconut oil had decreased ($P < 0.10$) olfactory acuity when pre-test threshold values obtained at week 4 were compared with values subsequently obtained at week 12 (Table 5). Likewise, EXE fed the control diet had significantly ($P < 0.10$) lower olfactory acuity when values obtained at week 4 were compared with values obtained at week 12. All remaining diet–physical conditioning combinations were similar ($P > 0.10$) across the study period. No evidence of olfactory function was present in NON dogs fed coconut oil at week 12 values (Table 5). It is important to note that these values were obtained prior to any physical exertion. The calculated percent change between pre-test olfactory values and post-test olfactory values indicated that EXE dogs and NON dogs fed diets B and C were not different ($P > 0.10$).

4. Discussion

The sport of field trials is one of the fastest growing outdoor activities in the United States. However, since the beginning of field competitions, trainers have searched for methods to improve canine performance. Holloway (1961) reported that 85% of hunting dog owners surveyed indicated some type of olfactory problem. Although the source of these conditions was not determined, olfactory function remains a primary concern for trainers of canine athletes. Myers and coworkers (1988a, 1988b, 1991b) have documented several conditions which affect the olfactory function of canines. These conditions include canine distemper and parainfluenza viral infections. However, these conditions are not believed to be the cause of impaired olfactory function in this study due to the fact that precautionary physical examinations, an aggressive vaccination program, and baseline olfactory measurements were performed prior to the initiation of the project. Additionally, all dogs were examined throughout the study and none displayed clinical signs of any upper respiratory or viral infection.

While some anecdotal evidence exists in the popular press, these data are the first to indicate scientifically a beneficial effect of physical conditioning on the olfactory acuity of canine athletes when subjected to moderate exercise. Behavioral olfactometry measurements revealed canine athletes enrolled in a physical conditioning program were able to maintain a greater olfactory acuity compared with dogs that were not physically conditioned. Non-conditioned dogs displayed a 63.6% decrease in olfactory acuity following treadmill exercise, while EXE dogs showed no significant changes (Table 4). These data may possibly be explained by altered respiratory function of the dogs during exercise. Dogs that are not in adequate physical condition breathe more through the mouth during periods of intense exercise as opposed to breathing through the nose when exposed to intense physical exertion. Because of increased heat load during exercise, dogs force more air through the lungs and out of the mouth to regulate body temperature. It is highly probable that decreasing the amount of airflow through the nasal passage reduces the amount of odorants passing over the olfactory membranes. This

Table 5
Effects of dietary fat source and physical conditioning on the olfactory thresholds of canine athletes throughout the project test period[1]

Conditioning[3]	Diet[2]						SEM
	Diet A		Diet B		Diet C		
	NON	EXE	NON	EXE	NON	EXE	
No. of dogs	3	3	3	3	3	3	
Week 4	18.0^a	12.0^a	11.0^a	11.3^a	18.0^a	12.0^a	2.9
Week 8	13.7^a	$7.7^{a,b}$	10.3^a	5.3^a	11.3^a	6.3^a	2.9
Week 12	15.0^a	4.7^b	4.7^a	6.0^a	0.0^b	11.0^a	2.9

[1] LSMeans ± SEM. Values represent the pre-stress test, values reported as the negative log of the minimum eugenol concentration, that elicited a behavioral response.

[2] Diets: Diet A, control containing 12% fat as beef tallow; Diet B (unsaturated), containing 16% fat (8% beef tallow and 8% corn oil); Diet C (saturated), containing 16% fat (8% beef tallow and 8% coconut oil).

[3] Conditioning: NON, non-conditioned; EXE, physically conditioned.

[a,b] Indicated differences within diet-conditioning group. Means within the same diet-conditioning group lacking a common superscript differ ($P < 0.10$).

mechanism could substantially reduce the ability of the athlete to detect odors both during and following periods of intense exercise. Likewise, increased dehydration of the nasal mucosal layer of poorly conditioned dogs would contribute to the altered function of the olfactory system due to total body dehydration.. It is highly probable that dehydration of the nasal mucosal membrane would result in decreased enzyme activity and decreased membrane fluidity. These conditions could alter neuro-signal transduction and odorant receptor function in the olfactory mucosal layer, thereby potentially impairing olfactory function in canine athletes. Conversely, a canine in top physical condition would be able to reduce the amount of air breathed through the mouth. Hydration status following exercise was not quantitatively measured in this experiment. Although the complete mechanism for decreased odor detection in non-conditioned canine athletes was not fully defined in this experiment, a combination of decreased airflow across the nasal membranes and/or decreased hydration status of the mucosal layer may significantly decrease odor detection capabilities in these canine athletes.

Several studies report alterations in functionality of organ and tissues in response to different dietary fat sources. Therefore, these diet-induced responses may also affect nasal epithelial composition and function when dogs are fed various fat sources. MacDonald et al. (1996) reported altered brain membrane phospholipid concentrations in rats during long term feeding of saturated versus unsaturated fatty acids. They reported that a diet comprised of saturated fatty acids resulted in a deficiency of 18:3 fatty acids in the brain. Membrane phospholipids provide a hydrophobic barrier between the environment and the cell (MacDonald et al., 1996). The fatty acid composition of membrane phospholipids dictates the fluidity and permeability of the membrane (Couture and Hulbert, 1995). Therefore, alteration of the membrane fatty acid composition may alter the function of the membrane due to changes in fluidity which, in turn, alters the function of membrane enzymes. While the complete olfaction mechanism is not defined, major components that mediate the molecular events of olfaction include one or more odorant-binding proteins, odorant-sensitive adenylate cyclase, and sodium-potassium ATPase. Sodium–potassium ATPase is one enzyme in brain synaptic membranes that has been reported to be altered by dietary fat (Gerbi et al., 1994).

Our data show a possible differential response to dietary fat source and exercise. Dietary fat source and(or) level did not alter the olfactory acuity of the physically conditioned (EXE) dogs. However, NON dogs fed coconut oil showed no evidence of odor detecting ability at week 12 of the study (Table 5). Similarly, EXE dogs fed the control diet had significantly reduced olfactory function prior to exercise when values obtained at week 4 were compared to values obtained at week 12 of the study. No differences were detected among the remaining diet-conditioning groups.

5. Summary

Physical conditioning of canine athletes prevented a reduction in olfactory acuity following one hour of treadmill exercise. Although further studies are required, these data indicate a beneficial effect of regular physical conditioning for canine athletes that are engaged in activities which require quality odorant-detecting capabilities. Additionally, feeding increased levels of saturated fatty acids to unconditioned dogs could result in poor olfactory detecting performance. While further investigations are warranted, data derived from this study suggest that high levels of saturated fat can further reduce the odorant-detecting capabilities of poorly conditioned canines. These factors should be considered when developing a training program for canine athletes.

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