

Evaluation of the Electronic Nose for Rapid Determination of Meat Freshness

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Story in Brief

The Electronic Nose was used to determine changes in lipid oxidation and microbial load of ground beef throughout simulated retail display. Aerobic, vacuum and CO₂ mixing treatments were also evaluated to determine their impact on Electronic Nose, lipid oxidation and microbial characteristics. Beef trim and ground beef were mixed in a commercial mixer with treatments Air-None, (AN), Vacuum-None, (VN), CO₂-None, (CN), Air-Air, (AA), Air-Vacuum, (AV), and Air-CO₂, (AC) where the first designation indicates beef trimming mixing conditions and the second designates ground beef mixing conditions. After grinding and mixing, ground beef was stored under simulated retail display, and analyzed at days 0, 1, 2, 3, 6, and 10. Analyses included Thiobarbituric Acid Reactive Substances (TBARS), Aerobic Plate Count (APC), and Electronic Nose characteristics. The Electronic Nose detected changes ($P < 0.05$) in ground beef lipid and microbial stability as did conventional TBARS and APC measures. Therefore, the Electronic nose may hold promise for rapid detection of meat freshness and safety.

Introduction

The challenges retail marketers encounter maintaining the shelf life of ground beef are due to color, lipid, and microbial stability. Increases in lipid oxidation have been observed in ground beef through retail display (Insausti et al., 1999). Likewise, the reduction of microorganisms in ground beef is critical to the Food Industry (Cutter and Siragusa, 1995) for safety and quality concerns. For lipid stability, thiobarbituric acid reactive substances (TBARS) testing has been used for the detection of malonaldehyde to estimate lipid oxidation of meat. While this procedure has been widely used, it is cumbersome and subject to error through lipid extraction procedures necessary to conduct the test. Therefore, it would be advantageous to have a rapid, nondestructive test that could indicate lipid and microbial characteristics of meat in real time. The Electronic Nose may provide a rapid means for assessing meat quality characteristics (Winqvist et al., 1993). Therefore, an experiment was designed to determine the relationship between Electronic Nose response to TBARS values and aerobic bacterial counts in ground beef. Additionally, the Electronic Nose was evaluated to determine the impact of meat mixing treatments on volatile responses.

Experimental Procedures

Ground beef processing and display. Beef trim meat was obtained in 300 lb lots. Each lot consisted of 6 (50.0 lb) batches. Six treatments were used to test the impact of aerobic, vacuum, and CO₂ mixing of beef trimmings and ground beef on Electronic Nose responses using a commercial mixer (Food Processing Equipment Co, Springdale, AR.). Beef trim followed by ground beef mixing treatments included Air-None (AN), Vacuum-none (VN), CO₂-none (CN), Air-Air (AA), Air-Vacuum (AV), and Air-CO₂ (AC).

For the first three treatments, beef trimmings were tumbled once, under the appropriate atmosphere, ground twice (Hobart Grinder, Model 310, Hobart Inc, Troy Ohio, USA) with a 3.2 mm plate, and packaged. For the remaining treatments, both beef trimmings and ground beef were mixed under the appropriate atmos-

phere. The first three treatments were mixed for 6 min and the last three treatments were mixed for 12 min (6 min for each half of the treatments). Liquid Food Grade CO₂ (P G Walker, Springdale, AR) was injected into the mixing chamber every 1 1/2 min during the CO₂ treatments. Vacuum treatments had vacuum applied to 15 mm mercury (Hg) with vacuum repeated as needed during a 6-min tumble to retain pressure.

All treatments of ground beef were packaged (1 lb) on styro-foam trays with absorbent paper diapers, over-wrapped with polyvinyl chloride film (oxygen transmission rate of 1400 cu/m²/24 h/1 atm; Borden Inc., Dallas, TX), and stored under simulated retail conditions (39°F; deluxe Phillips warm white fluorescent lighting, 1630 lux, Phillips Inc., Somerset, N.J.). Multiple trays of ground beef were stored at 3°F and sampled on days 0, 1, 2, 3, 6, and 10 for Electronic Nose and TBARS characteristics and aerobic plate count (APC). For each treatment, fat content was standardized to 10% (Hobart Fat Analyzer, Model F101, Hobart Inc., Troy, OH.). The pH was also measured by homogenizing 0.24 oz of ground beef in 2.4 oz of Millipore water with an Orion pH meter (Orion pH Meter, Orion Research, Inc., Beverly, MS).

Thiobarbituric acid reactive substances analysis. The TBARS assays were performed on ground beef using a modified procedure of Witte et al. (1970). The samples were stored in simulated retail conditions then frozen (-4°F) on days 0, 1, 2, 3, 6, and 10 of display. For TBARS analysis, three replicates from each treatment were sampled. A standard curve was made using TEP (1,1,3,3 tetraethoxypropane with concentrations from 0.088 ug/ml to 4.4 ug/ml in standard curve). For analysis, ground beef samples (0.07 oz) were mixed with 8 ml cold phosphate buffer (50 Mm phosphate buffer, 0.1% EDTA, 0.1% N-Propyl Gallate; Sigma Scientific, St. Louis, MO.) and homogenized using a Pro 250 Homogenizer (ProScientific, Monroe, CT.) Two ml 30% Trichloroacetic acid (Sigma Scientific, St. Louis, MO.) were added to each test tube and vortexed (Vortex Genie II Scientific Industries, Bohemia, NY). Samples were centrifuged (Beckman Tabletop Centrifuge GS-6, Palo Alto, CA) at 75°F and 4,000 rpm for 5 min. The supernatants were removed and added to 10 ml screw cap tubes. Two ml of TBARS reagent were added to each test tube. The samples were vortexed again. The standard curve and sample tubes were placed into a

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boiling water bath (General Signal, Blue Island, IL.) for 20 min. Tubes were next removed from the water bath and placed in an ice bath for 5 min. After removal from ice bath, tubes were stored in a refrigerator (Westinghouse, N.Y.) at 28°F for 30 min then centrifuged again at the same force. Absorbances at 533 nm were recorded in duplicate using a UV/VIS Spectrophotometer (Hewlett Packard, Vectra XM, Series 3, 5/75, Ponca City, OK.). The absorbance was multiplied by 12.21 and reported as TBARS in mg/kg sample (Mei et al., 1998.).

Microbial analyses. Ground beef packages were tested during simulated retail display at days 0, 3, and 10 for aerobic bacterial plate counts. Each 0.88 oz sample of ground beef was aseptically removed from the packages and placed in a sterile whirlpak bag (NASCO, Ft. Atkinson, WI) with 8.7 oz of 0.1% buffered peptone water. Samples were stomached (Stomacher, Model 400 Lab Stomacher, Seward, London, U.K.) for 60 sec. Next, samples were serially diluted and plated in duplicate on Aerobic Plate Count plates (PetriFilm, 3M Microbiologicals, St. Paul, Mn, USA). Plates were placed in an incubator (VWR Scientific Products Model 5015 Incubator, West Chester, Pa. USA) at 98.6°F for 48 ± 2 hr then read. Microbial counts were initially recorded as CFU/gram then converted to Log CFU/gram of sample.

Electronic Nose. On days 0, 1, 2, 3, 6 and 10 of display, ground beef packages were opened, sampled and evaluated for Electronic Nose (Electronic Nose Fox 4000, Alpha Moss Toulouse, France) characteristics in triplicate. Data were averaged to one data point. For evaluation, a 0.14 oz sample was aseptically removed from each package and placed in clean, volatile free 3.05 oz vials and sealed. Vials were placed in the Electronic Nose auto sampling tray and analyzed within each tray as one set of triplicate to help offset any baseline drift. The heating unit of the Electronic Nose heated samples to 122°F while agitating the sample vial to liberate volatiles. The gas-sampling syringe was heated to 41.0°F above sample temperature. Vapor generated in headspace of each sample vial was drawn out by the gas syringe and injected into the instrument for analysis by 12 sensors (Fox Sensor System, Toulouse, France). Heating syringes avoided condensation and possible sample contamination. The gas syringe was flushed by a carrier gas (20% oxygen, 80% Nitrogen; Hydrocarbon and water free) for avoidance of cross-contamination of samples.

Statistical analyses. The experiment was replicated three times. Treatments were blocked by replication and analyzed for the main effects of mixing treatment and days of display and their interaction using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Any variables involved in interactions were separated using the PDIF option of PROC GLM and subsequently plotted. Least squares means for all other variables were generated and separated using the PDIF option.

Results and Discussion

Effects of day and mixing treatments on Electronic Nose characterizations. We hypothesized that the Electronic Nose is capable of rancidity detection in ground beef in industrial applications for the retail shelf life estimation of ground beef. The Electronic Nose was able to detect increases or decreases in aromatic compounds (hydrocarbons, aldehydes, polar compounds) during the duration of simulated retail display ($P < 0.05$). Sensor 11 (T70/2) is commonly used for the detection of natural food aromas and volatiles. During display the Sensor 11 readings rose ($P < 0.05$) over a period of days of display (Table 1) in conjunction with the TBARS surface and APC

results (Table 2). Our findings are in agreement with those reported by Winqvist et al. (1993), Spanier et al. (1999), and Grigioni et al. (2000) indicating the Electronic Nose is capable of detecting meat volatile changes over a period of days of simulated display.

Sensor 2 (SY/g) is commonly used for the detection of meat and fish freshness. Response to Sensor 2 declined ($P < 0.05$) indicating a meat freshness decline with advancing duration of display (Table 1). The negative numbers suggest a volatile shift and change in detection. Likewise, the change in Sensor 2 response relates to changes in TBARS and APC values going up over the same period.

Mixing treatments did not produce any negative effects nor were there any differences ($P > 0.05$) among treatments shown for the first six sensors of the Electronic Nose (Table 3). However, the CN treatment tended to have the lowest odor detection for sensors 7 to 12 compared to all other treatments and control (AN). Furthermore, the data suggest that, although not significant at $P < 0.05$, volatiles detected by sensors 7 to 12 (Table 3) tended to be numerically reduced by adding CO₂ ground beef mixing after aerobic trim mixing (AC treatment) compared with AA or AV treatments. Sensors 7 to 12 cover the range of food aromas, cooking and roasting hydrocarbons, and alcohols. Our findings suggest it is possible to add Liquid Food Grade CO₂ prior to grinding beef trimmings to obtain better shelf life at the retail level as detected by the Electronic Nose.

Impact of mixing treatments on TBARS and microbial populations. TBARS and APC showed no significant differences ($P > 0.05$) between beef trim and ground beef mixing treatments (Table 4). The TBARS values showed that little lipid oxidation occurred in all treatments on ground beef surfaces, subsurfaces and a composite average of these two locations.

Implications

Data suggest the Electronic Nose has potential for the rapid detection of beef lipid stability and freshness determination in industrial applications. Utilizing technology such as this might aid in the exclusion of meat products with depressed quality and perhaps safety from consumer consumption.

Literature Cited

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Table 1. Impact of duration of ground beef simulated retail display on Electronic Nose sensor response.

Day	Sensor											
	1 ^a	2 ^b	3 ^c	4 ^d	5 ^e	6 ^f	7 ^g	8 ^h	9 ⁱ	10 ^j	11 ^k	12 ^l
0	0.0016 ^z	0.0009 ^x	-0.000 ^x	0.0006 ^x	0.0013 ^x	0.0012 ^x	0.0109 ^z	0.0111 ^z	0.0062 ^z	0.0101 ^z	0.0125 ^z	0.0129 ^z
1	0.0017 ^z	0.0009 ^x	-0.000 ^x	0.0004 ^x	0.0013 ^x	0.0013 ^x	0.0120 ^z	0.0130 ^z	0.0064 ^z	0.0118 ^z	0.0143 ^z	0.0153 ^z
2	0.0016 ^z	0.0006 ^x	-0.000 ^x	0.0003 ^x	0.0013 ^x	0.0012 ^x	0.0192 ^z	0.0236 ^z	0.0095 ^z	0.0216 ^z	0.0231 ^z	0.0265 ^z
3	0.0025 ^z	-0.001 ^x	-0.001 ^x	-0.001 ^x	-0.000 ^x	-0.000 ^x	0.0548 ^z	0.0757 ^z	0.0265 ^z	0.0693 ^z	0.0683 ^z	0.0821 ^z
6	0.0145 ^y	-0.017 ^y	-0.024 ^y	-0.017 ^y	-0.018 ^y	-0.015 ^y	0.4619 ^y	0.5569 ^y	0.3667 ^y	0.5393 ^y	0.4946 ^y	0.5830 ^y
10	0.0262 ^x	-0.037 ^z	-0.046 ^z	-0.036 ^z	-0.036 ^z	-0.031 ^z	0.5833 ^x	0.6776 ^x	0.4907 ^x	0.6594 ^x	0.6194 ^x	0.7038 ^x
SE	0.0029	0.0033	0.0043	0.0032	0.0027	0.0020	0.0259	0.0281	0.0266	0.0277	0.0206	0.0291

^a Sensor 1: Senses fluorinated, chlorinated, and aldehyde compounds.

^b Sensor 2: Senses meat and fish freshness.

^c Sensor 3: Senses hydrocarbon, methane, and propane.

^d Sensor 4: Senses paint, polymers, smoke.

^e Sensor 5: Senses alcoholic beverages, perfumes, fermentations.

^f Sensor 6: Senses cooking, roasting coffee, petrochemistries.

^g Sensor 7: Senses polar compounds, ethanols.

^h Sensor 8: Senses petrochemistries.

ⁱ Sensor 9: Senses cooking and roasting hydrocarbons.

^j Sensor 10: Same as sensor 1.

^k Sensor 11: Senses food aromas and volatiles.

^l Sensor 12: Senses alcohols, solvents.

^{xyz} Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

Table 2. Impact of duration of ground beef simulated retail display on thiobarbituric acid reactive substances (TBARS) and log aerobic plate count (APC) colony forming units per gram (CFU/g).

Day	TBARS (mg/kg)			APC (log CFU/g)
	Surface	Subsurface	Average	
0	0.76 ^y	1.01 ^{xy}	0.89 ^{xy}	2.92 ^z
1	0.83 ^y	0.69 ^y	0.76 ^x	
2	0.92 ^{xy}	1.02 ^{xy}	0.97 ^{xy}	
3	0.96 ^{xy}	0.93 ^{xy}	0.94 ^{xy}	4.80 ^y
6	1.01 ^{xy}	1.16 ^x	1.08 ^x	
10	1.14 ^x	0.94 ^{xy}	1.04 ^x	7.28 ^x
SE	0.09	0.13	0.09	0.01

^{xyz}Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

Table 3. Impact of ground beef mixing treatments on Electronic Nose sensor response.

Treatment	Sensor ^a											
	1	2	3	4	5	6	7	8	9	10	11	12
AN ^b	0.01	-0.01	-0.02	-0.01	-0.01	-0.01	0.21	0.25 ^{xy}	0.18	0.24 ^{xy}	0.23	0.26 ^{xy}
VN ^c	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.20	0.25 ^{xy}	0.17	0.24 ^{xy}	0.22	0.26 ^{xy}
CN ^d	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.15	0.17 ^y	0.11	0.17 ^y	0.16	0.18 ^y
AA ^e	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.19	0.23 ^{xy}	0.15	0.22 ^{xy}	0.21	0.24 ^{xy}
AV ^f	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.22	0.25 ^x	0.18	0.25 ^x	0.23	0.27 ^x
AC ^g	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.17	0.20 ^{xy}	0.13	0.19 ^{xy}	0.18	0.21 ^{xy}

^a See Table 1 for description of sensors.

^b Beef trimmings mixed aerobically, no ground beef mixing.

^c Beef trimmings mixed under vacuum, no ground beef mixing.

^d Beef trimmings mixed under carbon dioxide, no ground beef mixing.

^e Beef trimmings mixed aerobically, ground beef mixed aerobically.

^f Beef trimmings mixed aerobically, ground beef mixed under vacuum.

^g Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.

^{xyz} Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

Table 4. Impact of ground beef mixing treatments on thiobarbituric acid reactive substances (TBARS) and log aerobic plate count (APC) colony forming units per gram (CFU/g).

Treatment	TBARS (mg/kg) ^a			APC (log CFU/g) ^b
	Surface	Subsurface	Average	
AN ^c	0.93	0.84	0.88	5.04
VN ^d	1.03	1.05	1.04	5.01
CN ^e	0.97	0.99	0.98	4.97
AA ^f	0.78	0.94	0.86	4.92
AV ^g	0.91	0.91	0.91	5.00
AC ^h	0.98	1.02	1.00	5.05

^{ab} Least-squares means for TBARS values and APC did not differ ($P < 0.05$) among mixing treatments.

^c Beef trimmings mixed aerobically, not ground beef mixing.

^d Beef trimmings mixed aerobically, ground beef mixed aerobically.

^e Beef trimmings mixed aerobically, ground beef mixed under vacuum.

^f Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.

^g Beef trimmings mixed aerobically, ground beef mixed under vacuum.

^h Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.