Sensory methods used in meat lipid oxidation studies

by

Ronald Noble

B.S., Purdue University, 2012

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Food Sciences
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2018

Approved by:

Major Professor
Dr. Kadri Koppel

Abstract

Oxidation of meat decreases consumer acceptance and reduces market value making it an important problem for the meat industry. Odor and flavor of meat are significantly affected by lipid oxidation and researchers continue to explore new ways to control meat oxidation. Natural antioxidants, irradiation and oxygen treatments are major areas of research in meat lipid oxidation. In recent studies researchers have been exploring ways to extend shelf life of meat and in many case rely on sensory results. This report deals with sensory methods used to measure changes associated with treatments and outlines how researchers are using these methods.

Table of Contents

List of Tables

Acknowledgements

The Acknowledgements page is optional. If you include it, retain the Acknowledgements heading and enter your text here.

Dedication

The Dedication page is optional. If you include it, retain the Dedication heading and enter your text here.

Chapter 1 - Methods for meat lipid oxidation

Introduction

Lipid oxidation is the degradation of fatty acids into products such as hydroperoxides and lipid derived volatiles. The process of lipid oxidation is complex and can occur through auto-oxidation by free radicals, photo-oxidation, enzymatic oxidation and thermal oxidation. Auto-oxidation is a key mechanism in lipid oxidation of meat and occurs in a three stage process: initiation, propagation and termination (Naveena et al. 2013). Atmospheric oxygen is unreactive however other forms of oxygen such as superoxide, hydrogen peroxide and the hydroxyl radical are highly reactive. Autoxidation of lipids first requires reactive oxygen or free radicals to be present to initiate the auto-oxidation reaction. Free radicals to initiate lipid auto-oxidation form by photo-oxidation, lipoxygenases, metal catalysis or by other free radicals. Oxidation rate of pure lipids is well understood and mainly depends on the degree of unsaturation (Decker et al. 2010).

Measurement of rancidity in meat

Lipid oxidation produces a wide range of chemical compounds that can be measured to determine degree of rancidity. Various methods are available to measure oxidation compounds and it is up to the researcher to determine the best measurement strategy for product rancidity. Common methods include measurement of total hydroperoxide concentration and detection of specific secondary oxidation compounds. Titrimetric, spectroscopic and chromatographic techniques are available to measure selected rancidity indicators.

During initiation of auto-oxidation hydroperoxide compounds are formed and are referred to as primary oxidation compounds. Hydroperoxide concentration can be measured using a number of methods and is commonly reported as milliequivalents of peroxides in 1 kilogram of lipids. The most common and oldest method for detecting hydroperoxide concentration is the peroxide value (PV) method. The PV method is an iodometric assay where hydroperoxides are reacted with iodine ions to generate iodine, the resulting solution is then titrated with a reagent using starch solution as an indicator. Spectroscopic methods and chromatographic methods are available for measuring hydroperoxide concentration (Gotoh et al. 2011). The advantage of spectroscopic methods are that assays require minimal sample preparation and are useful when dealing with a product that has color added. Products of lipid oxidation contain different functional groups that allow their estimation using spectroscopic methods. Conjugated linoleic acids can be measured by spectroscopy allowing for the determination of total hydroperoxide concentration and PV (Decke et al. 2010).

Primary oxidation compounds do not produce undesirable characteristics in meat but they do degrade into secondary oxidation compounds which are responsible for undesirable flavors, odors and appearance. Titrimetric, spectroscopic and chromatographic techniques are available to measure concentration of secondary oxidation compounds. Aldehydes and other secondary compounds can be assessed by titration against sodium or potassium hydroxide using phenolphthalein as an indicator and expressed as the acid value. The thiobarbituric acid reactive substances (TBARs) test is a spectroscopic method used to measure secondary lipid oxidation compounds in meats and meat products. The secondary oxidation compound malondialdehyde turns pink when reacted with the thiobarbituric acid reagent to form a pink color chromophore that can be measured by spectroscopy. The resulting TBARs number is defined as milligrams of malondialdehyde present in 1kg of sample. Malondialdehyde is formed as a main product of oxidation of lipids when the associated fatty acids contain 3 or more double bonds. It should be taken into consideration that thiobarbituric acid will react with water soluble proteins, nitrites, aldehydes, sugars, nitrates, polyphenolic antioxidants, pigments, amino acids additives and fatty acids to form yellow or orange complexes. Various methods exist to eliminate interference produced by these compounds (Díaz et al. 2014).

Volatile secondary oxidation compounds associated with undesirable characteristics can be measured by gas chromatography mass spectroscopy (GC-MS), two common secondary compounds being hexanal and 2,4-decadienal. The advantage of using a chromatographic method to measure lipid oxidation is that specific compounds arising from the breakdown of specific fatty acids can be measured unlike with TBARs where values are non-specific and are a result of breakdown of many fatty acids and even other compounds. Studies have found correlations between TBARs, PV's and sensory characteristics of meat (Rhee & Myers, 2004). In 2006 Campo et al. found that at a TBARs value of 2 trained panelists could detect rancidity of beef. The direct analysis of malondialdehyde can only be achieved through high pressure liquid chromatography methods (HPLC) (Ponnampalam et al. 2014).

Appearance, texture and flavor are main indicators consumers use to judge meat products (Kerry 2009). Meat that has been oxidized develops rancid aromas and flavors. Aroma of meat plays an important role in consumer evaluation of meat quality. Once purchased, sensory qualities such as flavor drive consumer's evaluation of meat quality. There are typically 2 types of sensory panels that can be used to evaluate flavor and odor of meat; consumer panels and trained panels. Trained panels are typically used to determine if there is an overall difference between samples or to profile the different characteristics of a sample. Consumer panels are used to determine preference and acceptability of a product. It should be noted that classic sensory techniques for utilizing consumer panels or trained panels have been thoroughly outlined in a number of resources (Wheeler et al. 2015). In general, trained panelist should not be used for affective testing and consumer panels should not be used to conduct discrimination or descriptive testing. However, rapid methods do exist which utilize consumer panelists for descriptive and discrimination testing but these methods are not meant to replace classic trained panel methods. Currently scientists researching meat oxidation are utilizing both trained panelist and consumer panels to evaluate meats (Table 1).

Table 1 Summary of meat oxidation study methods

Panel	N	Treatment	Meat	Analytical	Sensory Method	Reference
Trained	16	Irradiation	Turkey, pork and beef	TBARs, volatiles	Preference and acceptability	Kim et al. 2002
Trained	16	Oxygen	Beef steaks	TBARs	Acceptability	Zakrys et al. 2009
Consumer	69	Tomato powder	Meatloaf	TBARs	Acceptability	Modzelewska-Kapituła 2012
Consumer	50	Oregano, sage and honey	Chicken breast and thigh	TBARs, hexanal	Preference and acceptability	Sampaio et al. 2012
Trained	15	Rye and wheat bran extract	Hamburger	TBARs, hexanal	Descriptive analysis	Šulniūtė et al. 2016
Experienced	10	Guava powder	Sheep meat nuggets	TBARs	Acceptability	Verma et al. 2013
Trained	10	mate	Chicken meatballs	none	Discrimination	Racanicci et al.2009
Consumer	70	Cinnamon deodorized aqueous extract	Chicken meatballs	TBARs,PV, FFA	Acceptability	Chan, et al. 2012
Trained	10	Bael pulp residue	Goat meat nuggets	TBARs	Acceptability	Das et al. 2014
Trained	7	Broccoli powder	Goat meat nuggets	TBARs	Acceptability	Banerjee, et al. 2012
Consumer	18	Dried citrus extract	Turkey meat slices	TBARs	Acceptability	Contini, et al. 2014
Trained	14	Rooibos tea extract	Ostrich meat sausage	TBARs	Descriptive analysis	Hoffman et al.2014
Trained	10	Rooibos tea extract	Blesbok and Spring bok meat sausages	TBARs	Descriptive analysis	Jones et al. 2015
Trained	10	Litchi pericarp extract	Sheep meat nuggets	TBARs	Acceptability	Das, et al. 2016
Consumer	10	Carnosic and rosmarinic acid	Chicken patties	TBARs,PV, FFA	Acceptability	Maheswarappa et al. 2013

Trained	7	Marjoram and rosemary essential oils	Beef and mechanically deboned chicken patties	TBARs	Descriptive analysis and acceptability	Mohamed & Mansour, 2012
Trained	7	Marjoram, rosemary and sage extract	Ground beef	TBARs	Descriptive analysis and acceptability	Mohamed, Mansour, & Farag, 2011
Trained	10	Garlic and onion	Ground beef	TBARs and volatiles	Descriptive analysis	Yang, et al., 2011

Acceptability and preference testing

Researchers have used trained panelists to conduct acceptance and preferences testing of meat products in a number of studies. For example in 2002 Kim et al. analyzed irradiated meat from different animal species with a 16 member trained panel. Acceptance and forced preference testing were conducted on irradiated turkey, pork and beef samples. In this study TBARs testing showed that irradiation promoted lipid oxidation regardless of the animal species treated. Analysis of volatile compounds in the meats showed that irradiation increased total volatiles independent of animal species. The hedonic scores produced by the 16 trained panelists indicated that only turkey meat showed significant differences for liking of odor between irradiated and nonirradiated samples. However, these sensory results were not produced by a consumer panel of adequate size and are potentially biased.

In 2009 a study conducted by Zakrys et al. also used a 16 member trained panel to evaluate acceptance, preference and descriptive profile of beef steaks packed with various levels of oxygen. Panelists were screened on the basis that they consume and purchase modified atmosphere beef regularly. Panel members were familiar with oxidized meat flavor and were told the sensory descriptor for oxidized flavor is rancid, cardboard or linseed oil like flavor. Descriptive analysis, acceptance and preference testing of steak flavor and color were conducted in the same session. TBARs testing validated that beef packed with higher oxygen levels had higher levels of oxidation. Although the acceptance and preference results were not produced using consumers, Zakrys et al. suggested that consumers have high acceptability for oxidized flavor.

In another study conducted in 2013 by Verma et al. a 10 member experienced panel was used to perform hedonic testing on sheep meat nuggets treated with guava powder. Experienced panelists used an 8 point scale to evaluate acceptability of flavor, juiciness, texture, appearance and overall acceptability. TBARs scores were collected over 15 days at 4 °C storage. TBARs values indicated that nuggets that contained 1% guava powder had comparable performance to nuggets containing 0.1% BHT over a 15 day 4°C shelf life. Verma, et al. reported that there were not significant differences in acceptance of flavor, juiciness, texture appearance and overall acceptance but these results were not produced using an adequate number of consumer panelists.

In 2014 Das et al. also used a 10 member experienced panel to evaluate acceptability of meat product. Das et al. studied the effect of bael pulp residue had on oxidation of cooked goat meat nuggets. Panelists used an 8 point hedonic scale for liking of appearance, flavor, juiciness, texture and overall acceptability. Cooked nuggets were refrigerated for 21 days and evaluated for TBARs and acceptance. Nuggets treated with 0.25% or 0.5% had significantly lower TBARs values than untreated nuggets. Das et al. (2014) suggested that using bael pulp residue at 0.5% significantly increased acceptability of appearance of goat meat nuggets. Das et al. (2014) also suggested that bael pulp residue used at either 0.25% or 0.5% does not significantly affect acceptance of flavor, texture, juiciness and overall acceptability of goat meat nuggets. In order to draw this conclusion, consumer panelists should be used in place of experienced panelists.

In 2012 Banerjee et al. used trained panelists to conduct acceptability testing on goat meat nuggets treated with broccoli powder. Cooked nuggets were evaluated for lipid oxidation by TBARs over 16 days of refrigerated storage. Banerjee et al. (2012) showed a significant difference in TBARs values between untreated nuggets and nuggets treated with broccoli powder. Nuggets treated with 2% broccoli powder had TBARs values similar to nuggets treated with BHT. Acceptability testing with the trained panelists indicated there were not significant differences in acceptability of appearance, flavor, texture, juiciness or overall acceptability between nuggets treated with broccoli powder or BHT. To draw this conclusion a consumer panel should be used in place of a trained panel.

When conducting affective testing it is important to recruit an adequate size of the correct consumers for the topic of interests. This can be a difficult task and recent meat oxidation studies utilizing consumer panelists reflect this. For example in 2013 Maheswarappa et al. used a small 8 to 10 person panel to measure acceptability of cooked chicken patties treated with carnosic and rosmarinic acids. TBARs, PV and total free fatty acids were measured to monitor lipid oxidation. Raw patties were monitored over 9 days and cooked patties over 21 days. Sensory evaluation was only conducted on day 0. Uncooked patties treated with carnosic and rosmarinic acid had significantly lower TBARs values and PV over 9 days of storage. Cooked patties treated with carnosic and rosmarinic acid had significantly lower TBARs values and PV over 21 days of storage compared to untreated patties. No differences were observed in free fatty acids in uncooked or cooked patties. No significant differences in acceptability was observed between treated or untreated patties. However, the acceptability results were determined by a small sample size of consumers and could have been biased.

In 2011 Mohamed et al. conducted acceptability testing on irradiated refrigerated ground beef treated with marjoram, rosemary and sage extract using a 7 person trained panel. A 7 point hedonic scale was used for overall acceptability. TBARs values were collected over 12 days of refrigerated storage. Adding marjoram, rosemary and sage extract significantly reduced TBARs values during refrigerated storage. Irradiation did significantly affect overall acceptability. Adding rosemary, sage or marjoram extract significantly increased acceptability of irradiated beef. These acceptability results were not produced utilizing a consumer panel and may not represent true consumer response.

In 2016 Das et al. also used a small consumer panel consisting of 10 members to evaluate acceptability of sheep meat nuggets treated with litchi pericarp extract. Lipid oxidation of cooked sheep meat nuggets was monitored over 12 days of refrigerated storage by measuring TBARs values. Control nuggets reached a maximum TBARs value of 1.2 mg MDA/kg. Nuggets treated with 1.5% litchi pericarp extract had significantly lower TBARs values than untreated nuggets and performed similar to nuggets treated with 100 ppm BHT. There were not significant differences in acceptability of treated nuggets versus untreated nuggets but due to such a small sample size of consumers these results may not reflect true consumer response.

In 2014 Contini et al. evaluated cooked turkey meat slices treated with dried citrus extract for lipid oxidation over 4 days of refrigerated storage. An 18 member consumer panel was used to conduct forced preference and acceptance testing. Cooked turkey slices treated with dried citrus extract had significantly lower TBARs values than untreated slices. There were significant differences in odor between treated and untreated slices after 4 days of refrigerated storage.

There were no significant differences in taste after 4 days of storage. Slices stored on PET treated with dried citrus extract received significantly higher preference scores using the 18 member consumer panel. Overall acceptability and tenderness scores were significantly higher in sliced stored on PET treated with dried citrus extract. There were no significant differences in acceptability of flavor and juiciness. Contini et al. 2014 showed that dried citrus extract did not have an effect on sensory properties of turkey meat slices and that dried citrus extract increased acceptability and preference after 4 days of refrigerated storage but due to a small the small sample set these results may not reflect true consumer response.

Various studies in recent literature are performing affective testing with relatively large consumer panels. For example in 2012 Modzelewska-Kapituła evaluated meatloaf treated with tomato powder for lipid rancidity using TBARs testing at 1, 7 and 14 days of shelf life. Acceptability testing was conducted with 69 consumers in order to determine if tomato powder had an effect on acceptability of meatloaf. Panelists used a 5 point hedonic scale to evaluate the meatloaf for acceptability of flavor, appearance, cross section color and consistency. Meatloaf treated with tomato powder did not test lower for TBARs values indicating tomato powder had no effect on inhibiting lipid oxidation. There were no significant differences in scores between control and tomato powder treatments for flavor indicating that tomato powder did not affect consumer acceptability. There were significant differences in internal color of meatloaf but this was not due to inhibition of lipid oxidation. In this study Modzelewska-Kapituła showed that tomato powder did not inhibit oxidation and that tomato powder did not affect the flavor of the meatloaf.

In another study conducted by 2012 Sampaio et al. the researchers used a 50 member consumer panel to evaluate the effect oregano, sage and honey had on acceptability and preference of cooked chicken breasts and thighs. Consumers evaluated chicken samples for acceptance using a 9 point scale for liking. Consumers also assigned order of preference to the samples. Chicken samples were evaluated at 0, 48 and 96 hours in refrigerated storage for hexanal content and TBARs values. Sampaio et al. 2012 showed that chicken treated with oregano, sage and honey had significantly lower TBARs values and hexanal content than chicken treated with BHT or chicken with no antioxidant treatment. Chicken treated with BHT and chicken with no antioxidant were not evaluated by the consumer panel. Chicken treated with oregano, sage and honey were evaluated and showed high acceptance scores. There were no significant difference between oregano, sage and honey treatments for acceptance. The chicken treated in combination with oregano, sage and 5% honey were significantly preferred. Sampaio et al. 2012 showed in this study that the natural antioxidants oregano, sage and honey inhibited lipid oxidation more than untreated chicken and BHT over a 96 day refrigerated shelf life. The study also showed that consumers have high acceptability for chicken treated with these natural antioxidants. In 2012 Chan et al. also used a large consumer panel consisting of 70 panelists to determine acceptability of refrigerated cooked chicken meatballs treated with cinnamon deodorized aqueous extract. Meatballs treated with 200 ppm of the extract had peroxide values and TBARs values comparable to meatballs treated with 200 ppm BHT and BHA. Chan et al. 2012 showed that there were not significant differences in acceptability of color, aroma, taste, texture and overall acceptance of meatballs treated with cinnamon deodorized extract, ascorbic acid, BHT and BHA.

Descriptive analysis and discrimination testing

In 2011 Brito et al. performed descriptive analysis on irradiated mechanically deboned chicken meat using a 9 person trained panel. Panelists were trained for 6 45 minute sessions with non-irradiated samples and irradiated samples. After the 7th day of storage TBARs values for irradiated samples were significantly higher than non-irradiated samples. The only significant difference in irradiated odor perception was on day 0 with non-irradiated samples having significantly lower scores than irradiated samples. For oxidized odor the samples dosed with less radiation showed a significant difference in oxidized odor when compared to the sample dosed with a higher amount of radiation at days 0 and 2. In this study oxidation of meat was detected using both instrumental and sensory methods. However, it is important to note that TBARs testing did not show differences in oxidation until after 7 days of storage but trained panelists could detect oxidation at 0 and 2 days of storage.

In 2014 Contini et al. evaluated cooked turkey meat slices treated with dried citrus extract for lipid oxidation over 4 days of refrigerated storage. An 18 member consumer panel was used to conduct discrimination testing. Cooked turkey slices treated with dried citrus extract had significantly lower TBARs values than untreated slices. Triangle test results indicated that panelists could not discriminate between treated and untreated turkey slices. TBARs values alone would lead one to believe dried citrus extract is necessary to prevent oxidation spoilage but sensory results allow more meaning to be drawn from these type of experiments. Furthermore, discrimination testing does not require intensive training or very large panels making it an attractive form of testing treatments effects on meat products.

In 2014 Hoffman et al. evaluated dried ready to eat ostrich meat sausages treated with tea extract. Descriptive analysis was conducted with a 14 member trained panel during a 15 day storage period. Panel members were trained on descriptors over three 90 minute sessions. There were not significant differences in TBARs values between treated or untreated sausages over 15 days of storage. Trained panelists were able to distinguish aroma and flavor of sausages treated with tea extract with untreated sausages having significantly lower scores for rooibos tea aroma and flavor. Untreated sausages had significantly higher fresh fatty aroma. No rancid aroma or flavor was detected in treated or untreated sausages. Rooibos tea extract did not slow down lipid oxidation in ready to eat ostrich sausages. When rooibos tea extract was used at 1% it acted as a pro-oxidant. The main attributes observed by trained panelists were rooibos, smoky, fresh fatty and game aromas and flavors. The trained panelists were able to identify changes that the TBARs testing could not.

In 2016 Šulniūtė et al. used descriptive analysis with a 15 member trained panel to evaluate hamburgers treated with natural antioxidants extracted from rye and wheat bran. Odor, homogeneity, intensity of color, superficial humidity and discoloration were evaluated over a 15 day shelf life. Hexanal and TBARs values were significantly lower in hamburger treated with cereal bran extract than hamburger without antioxidant over the shelf life. Odor was significantly more intense in hamburger at the end of storage. Detailed results from descriptive analysis were not included in this study.

In 2015 Jones et al. used descriptive analysis and 10 trained panelists to test the efficacy of rooibos tea extract in reducing lipid oxidation of ready to eat dried sausages made from blesbok and springbok meat. Panelists were trained during three 90 minute sessions on aroma, appearance, flavor and texture attributes. Panelists were able to detect rooibos tea extract aroma and flavor in ready to eat dried sausages made from blesbok or springbok meat. Game aroma and flavor decreased as rooibos tea extract increased. Fatty aroma decreased as levels of rooibos tea extract increased. No rancidity was detected in treated or untreated sausages. There were no differences in appearance or texture in treated or untreated sausages. TBARs values indicated that lipid oxidation over 2 weeks of storage significantly decreased as rooibos tea extract increased. This study indicated that TBARs testing cannot always be relied on for making antioxidant dosage decisions and shows the value of utilizing sensory testing.

In 2014 Karwowska & Dolatowski performed descriptive analysis on pork treated with mustard seed extract using 8 trained panelists. Panelists were familiar with descriptive analysis and used defined attributes for rancid odor and flavor. TBARs values were collected over 12 days of refrigerated storage. Pork treated with mustard seed extract had significantly lower TBARs values than untreated pork. Addition of mustard seed extract did not significantly influence sensory attributes tested including rancid odor and flavor. This study is another good example of when sensory results are necessary in detecting meaningful characteristics associated with shelf life.

In 2012 Mohamed & Mansour used a 7 person experienced panel to perform descriptive analysis and acceptability testing on frozen beef and mechanically deboned chicken meat patties treated with marjoram and rosemary essential oils. Lipid oxidation was monitored over 3 months by TBARs testing. Panelists rated the samples using a 7 point intensity scale for flavor, juiciness, and firmness over 3 months of storage at -18°C. Mohamed et al. found that patties treated with marjoram and rosemary extract had significantly lower TBARs values than patties treated with BHT. The panelists detected rancid flavor in samples that were not treated with antioxidants. Untreated samples received significantly lower flavor scores than treated samples. The addition of antioxidants significantly increased flavor scores during 3 months of frozen storage.

In 2011 Mohamed et al. conducted descriptive analysis and acceptability testing on irradiated refrigerated ground beef treated with marjoram, rosemary and sage extract using a 7 person trained panel. Panelists were trained in a single session on their ability to distinguish irradiation odor from other odors. A 7 point intensity scale was used for irradiation odor as well as overall acceptability. TBARs values were collected over 12 days of refrigerated storage. Adding marjoram, rosemary and sage extract significantly reduced TBARs values during refrigerated storage. Samples treated with marjoram followed by irradiation were significantly lower than samples treated with rosemary or sage followed by irradiation. All 3 herbal extracts significantly reduced irradiation odor. Panelists could not detect irradiation odor in samples treated with marjoram until after the 8th day of storage. Panelists could not detect irradiation odor in samples treated with sage until after the 5th day and 12th day of storage. Panelists could not detect irradiation odor of samples treated with rosemary until after the 19th and 26th day of storage. Mohamed et al. 2011 also conducted acceptability testing using the 7 person trained panel and reported that addition of the herbal extracts did not significantly affect overall acceptability scores but irradiation did significantly reduce overall acceptability. However, adding rosemary, sage or marjoram extract significantly increased acceptability of irradiated beef. These acceptance results were not conducted with a consumer panel and likely do not reflect real consumer response.

In 2011 Yang, et al. conducted descriptive analysis of irradiated ground beef treated with garlic and onion using a 10 member trained panel. Panelists were trained on references for beef odor, irradiated odor and onion/garlic odor using laboratory made standards. TBARs values and volatiles were tested over 7 days of refrigerated storage to detect lipid oxidation products. . TBARs values of irradiated samples were significantly higher than non-irradiated samples throughout storage. TBARs values of beef were treated had significantly lower TBARs values than untreated over the 7 days of storage. Irradiated beef produced significantly more volatile aldehydes than non-irradiated beef with hexanal being the dominant aldehyde being produced.

Irradiation aroma was significantly higher in irradiated beef than in non-irradiated beef. Addition of 0.5% onion did not significantly alter intensity of irradiated odor. Treatments of 0.1% garlic or 0.1% garlic and 0.5% onion significantly reduced intensity of irradiated odor

In 2009 Racanicci, Allesen-Holm, and Skibsted used a trained discrimination panel to evaluate precooked chicken meatballs treated with mate. Triangle tests were conducted with 10 trained panelists to evaluated taste and smell differences of chicken meatballs made with mate extract and dried mate leaves used at 0.0% 0.05% and 0.1% usage rates. Panelist were able to detect a significant difference in smell for meatballs containing either 0.1% mate extract or 0.1% mate leaves when compared to control. Panelists were not able to detect differences in taste in meatballs containing 0.1% mate extract. However, panelists were able to detect difference in taste when meatballs contained 0.1% mate leaves.

Discussion

A majority of current meat lipid oxidation studies involve natural antioxidant treatments. Das et al. 2013, Maheswarappa et al. 2013, Banerjee et al. 2012, Chan et al. 2012,Verma et al. 2013, Sampaio et al. 2012, and Modzelewska-Kapitula 2012, all performed meat lipid oxidation studies involving natural antioxidant treatments. Each study used acceptability testing to determine if a treatment had an effect on initial acceptability of meat. Acceptability testing was not conducted over storage time, instead TBARs testing or other analytical methods were used to monitor lipid oxidation. Oregano, sage and honey significantly increased acceptance of chicken before storage. All other natural antioxidant treatments had no significant effect on acceptance before storage. Natural antioxidants reduced analytical markers for lipid oxidation in all treatments except tomato powder. Acceptability results at the end of storage were not collected in these studies. In these studies analytical results were heavily relied on to track oxidation of meat. Moreover, many of these studies utilize trained panelists to perform acceptance and preference testing. Testing acceptability and preference at the end of shelf life using a panel of consumers would produce valuable results.

Table 2 Acceptance and preference testing in meat lipid oxidation studies

Panel	N	Treatment	Meat	Analytical	Sensory Method	Reference
Trained	16	Irradiation	Turkey, pork and beef	TBARs, volatiles	Preference and acceptability	Kim, Nam, & Ahn 2002
Trained	16	Oxygen	Beef steaks	TBARs	Acceptability	Zakrys et al. 2009
Consumer	69	Tomato powder	Meatloaf	TBARs	Acceptability	Modzelewska-Kapituła 2012
Consumer	50	Oregano, sage and honey	Chicken breast and thigh	TBARs, hexanal	Preference and acceptability	Sampaio et al. 2012
Trained	10	Guava powder	Sheep meat nuggets	TBARs	Acceptability	Verma et al. 2013
Consumer	70	Cinnamon deodorized aqueous extract	Chicken meatballs	TBARs,PV, FFA	Acceptability	Chan, et al. 2012
Trained	10	Bael pulp residue	Goat meat nuggets	TBARs	Acceptability	Das et al. 2014
Trained	7	Broccoli powder	Goat meat nuggets	TBARs	Acceptability	Banerjee et al. 2012
Consumer	18	Dried citrus extract	Turkey meat slices	TBARs	Preference, acceptability and discrimination	Contini, et al. 2014
Trained	10	Litchi pericarp extract	Sheep meat nuggets	TBARs	Acceptability	Das, et al. 2016
Trained	7	Irradiation, marjoram, rosemary and sage extract	Ground beef	TBARs	Acceptability and descriptive analysis	Mohamed et al. 2011
Consumer	10	Carnosic and rosmarinic acid	Chicken patties	TBARs,PV, FFA	Acceptability	Maheswarappa, et al. 2013

In recent literature regarding meat lipid oxidation researchers have been using discrimination testing and descriptive analysis to analyze the effects natural antioxidants and irradiation have on sensory attributes over time. These studies utilize trained panelists to evaluate intensities of odors and flavors.

Brito et al. 2011 evaluated mechanically de-boned chicken treated with irradiation. TBARs values were significantly higher in mechanically deboned chicken treated with irradiation over the storage period. Irradiated odor and oxidized odor was significantly more intense in treated samples until the end of storage. In another study conducted by Yang et al. 2011 studied the effects irradiation, garlic and onion treatments have on ground beef odor. Trained panelists were used to measure intensity of irradiation odor over time. TBARs values were significantly higher in irradiated ground beef and irradiation odor intensity was significantly higher in irradiated ground beef. Addition of onion and garlic to irradiated samples significantly reduced irradiation odor intensity. In these studies by Brito et al. 2011 and Yang et al. 2011 were able to detect odors associated with meat oxidation using trained panelists. In both studies TBARs values were significantly higher is products that scored higher for oxidized odors. These studies suggest that descriptive analysis intensity scores can identify lipid oxidation in ground beef and mechanically deboned chicken. Furthermore, these studies suggest that TBARs value could be correlated to descriptive sensory results but TBARs thresholds for sensory changes is likely product dependent.

Šulniūtė et al. 2016, Mohamed & Mansour 2012, Mohamed et al. 2011, and Karwowska & Dolatowski 2014 studied the effect various natural antioxidants had on lipid oxidation of meats. In these studies analytical measurements were conducted alongside descriptive analysis of oxidized odor, flavor and treatment odor and flavor. All studies showed that natural antioxidants decreased TBARs values but not all studies showed a decrease in intensity of oxidized odor and flavor. Karwowska & Dolatowski studied pork treated with mustard seed extract. Results showed no significant differences in flavor and odor intensities between treated and untreated pork. There were significant differences in TBARs values between untreated and treated pork. These studies further indicate that TBARs thresholds for sensory changes are product dependent.

Contini et al. 2014 and Hofman et al. 2014 studied the effect rooibos tea extract had on lipid oxidation of dried ready to eat sausages made with ostrich, blesbok and spring bok meat. In these studies there were no significant difference in TBARs values over all treatments during storage. There were also no significant differences in oxidized odor intensity across all treatments during storage. However, there was significant differences in rooibos tea extract odor intensity with treated meat having significantly higher treatment odor intensity scores. These studies show that descriptive analysis is a useful tool for identifying sensory changes associated with treatment level.

Meat products are complex matrixes containing many flavor and odor compounds. Thresholds for detection of oxidized odor or flavor intensity by trained panelists are evident in these studies. Descriptive analysis is a powerful method that gives insight beyond analytical testing. It is a tool that these researchers are using to verify lipid oxidation changes in the meats they study. However, flavor intensity and odor intensity results do not give insight to how consumers will respond to these sensory changes. Overall, in these studies descriptive analysis was able to identify if oxidation changes occurred in the meats studied and provide potential thresholds for analytical results.

Contini et al. and Racanicci et al. utilized discrimination testing to evaluated natural antioxidants effect on chicken meatballs and turkey meat slices. Racanicci et al. performed 2 triangles tests on chicken meatballs treated with mate extract and mate leaves. Results showed that chicken meatballs treated with either mate extract or mate leaves were significantly different than untreated chicken meatballs. Storage and analytical testing was not performed to measure lipid oxidation. Contini et al. performed triangle testing on turkey meat slices stored in packaging treated with citrus extract. TBARs values were significantly lower in treated samples over the storage time. Panelists could not discriminate between samples based on flavor. However, panelists were able to discriminate between untreated and treated samples based on odor at the end of storage. This study shows the importance of utilizing sensory results in to determine the effects of product quality due to oxidation.

Table 3 Descriptive analysis and discrimination testing in meat lipid oxidation studies

Panel	N	Treatment	Meat	Analytical	Sensory Method	Reference
Trained	9	Irradiation	Mechanically deboned chicken meat	TBARs	Descriptive analysis	Brito et al. 2011
Trained	15	Rye and wheat bran extract	Hamburger	TBARs, hexanal	Descriptive analysis	Šulniūtė et al. 2016
Trained	10	mate	Chicken meatballs	none	Discrimination	Racanicci et al. 2009
Consumer	18	Dried citrus extract	Turkey meat slices	TBARs	Preference, acceptability and discrimination	Contini, et al. 2014
Trained	14	Rooibos tea extract	Ostrich meat sausage	TBARs	Descriptive analysis	Hoffman et al. 2014
Trained	10	Rooibos tea extract	Blesbok and Spring bok meat sausages	TBARs	Descriptive analysis	Jones et al. 2015
Experienced	7	Marjoram and rosemary extract	Beef and mechanically deboned chicken patties	TBARs	Descriptive analysis	Mohamed & Mansour, 2012

Experienced	7	Mechanically deboned chicken, marjoram, rosemary and sage extract	Ground beef	TBARs	Acceptability and descriptive analysis	Mohamed et al. 2011
Trained	8	Mustard seed extract	pork	TBARs	Descriptive analysis	Karwowska & Dolatowski
Trained	10	Irradiation, garlic and onion	Ground beef	TBARs and volatiles	Descriptive analysis	Yang, et al., 2011

Descriptive analysis and discrimination testing use trained panelists to identify differences in products. Various methods exist for both descriptive analysis and discrimination testing. Descriptive analysis testing typically requires a lengthy training process with reference products. In current meat lipid oxidation studies involving descriptive analysis trained panelists are often not adequately trained. Many of these studies did not use reference standards to train panelists (table 4 and 5). In many cases only a brief description of the odor or flavor attribute was given. Recruiting and training a panel is a challenging task

Discrimination panels typically require less training but require a larger number of trained panelists than descriptive panels. Racanicci et al. used 10 panelists and Contini et al. used 18 panelists to perform triangle testing on meat products treated with natural antioxidants. This is typically not an adequate number of panelists to perform this discrimination test. Although differences were not found between untreated and treated products there cannot be confidence that these results are repeatable. Typically discrimination panels require at least 30 panelists that are screened for ability to taste and smell and that are trained on the discrimination methods. This is a substantially smaller panel when compared to the requirements for a consumer panel. Training is also minimal in comparison to descriptive analysis. Meat lipid oxidation studies may benefit from the used of discrimination testing due to relatively small panel size and training requirements.

Table 4 Aroma attributes used to train panelists in meat lipid oxidation studies

Aroma attributes used in descriptive analysis of oxidized meat			
Attribute	Definition	Reference Standard	Reference
Fatty	Associated with fresh non-oxidized fat	No	Jones, et al.2015
Rancid	Associated with oxidized fat	No	Jones et al. 2015
Rancid	Associated with oxidized fat	No	Hoffman et al. 2014
Rooibos extract	Associated with sweet, woody aroma typical of rooibos	No	Hoffman et al. 2014
Irradiated	Rotten egg, bloody, fishy, burnt, sulphur, metallic, alcohol or acetic acid	No	Mohamed et al. 2011
Odor of oxidation	Odor of fat of oxidized chicken	Yes	Brito, et al., 2011
Odor of irradiation	Odor of burnt chicken skin after manual feather plucking the feathers are scorched over flame to facilitate manual removal of feathers	Yes	Brito et al. 2011
Rancid odor	Odor associated with oxidation compound derived from fat	No	Karwowska & Dolatowski 2014

Table 5 Flavor descriptors used to train panelists in meat lipid oxidation studies

Aroma attributes used in descriptive analysis of oxidized meat			
Attribute	Definition	Reference Standard	Reference
Fatty	Associated with fresh non-oxidized fat	No	Jones et al. 2015
Rancid	Associated with oxidated fat	No	Jones et al. 2015

Rancid	Associated with oxidated fat	No	Hoffman et al.2014
Rooibos extract	Associated with sweet, woody aroma typical of rooibos	No	Hoffman et al.2014
Irradiated	Rotten egg, bloody, fishy, burnt, sulphur, metallic, alcohol or acetic acid	No	Mohamed et al. 2011
Odor of oxidation	Odor of fat of oxidized chicken	Yes	Brito et al. 2011
Odor of irradiation	Odor of burnt chicken skin after manual feather plucking the feathers are scorched over flame to facilitate manual removal of feathers	Yes	Brito, et al., 2011
Rancid odor	Odor associated with oxidation compound derived from fat	No	Karwowska & Dolatowski 2014

Conclusion

In recent meat lipid oxidation studies researchers have been using descriptive analysis, acceptability, preference and discrimination testing in combination with analytical markers to study the effects various treatments have on meats. These studies heavily rely on instrumental results such as TBARs values to evaluate treatment effects on meat. Small trained panels are frequently being used in place of consumers to evaluate acceptability and preference of meat. This may be due to the challenging task of recruiting large consumer panels for multiple sampling points in a study. Current research involving descriptive analysis of meat lipid oxidation is often utilizing panelists that are not adequately trained. The miss use of these sensory methods may be due to a lack of resources for conducting sensory analysis. Correctly utilizing sensory methods in meat oxidation studies would allow researchers to gain more meaning from instrumental results such as TBARs values. These studies show the potential and power of sensory methods, even when they are not being optimized.

References

Adhikari, Koushik, Edgar Chambers Iv, Rhonda Miller, Laura Vázquez-Araújo, Natnicha Bhumiratana, and Chrisly Philip. "Development Of A Lexicon For Beef Flavor In Intact Muscle." *Journal of Sensory Studies* 26.6 (2011): 413-20. Web. 27 Mar. 2017.

Banerjee, Rituparna, Arun K. Verma, Arun K. Das, V. Rajkumar, A.a. Shewalkar, and H.p. Narkhede. "Antioxidant effects of broccoli powder extract in goat meat nuggets." *Meat Science* 91.2 (2012): 179-84. Web. 24 Feb. 2017.

Brito, Poliana P., Heliana Azevedo, Kátia M. V. A. B. Cipolli, Henrique T. Fukuma, Gerson B.

Mourão, Cláudio V. Roque, Norma T. Miya, and José L. Pereira. "Effect of the Gamma Radiation Dose Rate on Psychrotrophic Bacteria, Thiobarbituric Acid Reactive Substances, and Sensory Characteristics of Mechanically Deboned Chicken Meat." *Journal of Food Science* 76.2 (2011): n. pag. Web. 21 Mar. 2017.

Byrne, Derek V., Wender L.p. Bredie, and Magni Martens. "Development of A Sensory Vocabulary For Warmed-Over Flavor: Part Ii. In Chicken Meat." *Journal of Sensory Studies* 14.1 (1999): 67-78. Web. 27 Mar. 2017.

Campo, M.m., G.r. Nute, S.i. Hughes, M. Enser, J.d. Wood, and R.i. Richardson. "Flavour perception of oxidation in beef." *Meat Science* 72.2 (2006): 303-11. Web. 25 Feb. 2017.

Chan, Kim Wei, Nicholas M. H. Khong, Shahid Iqbal, Soo Ee Ch'Ng, Umer Younas, and Abdul Salam Babji. "Cinnamon bark deodorised aqueous extract as potential natural antioxidant in meat emulsion system: a comparative study with synthetic and natural food antioxidants." *Journal of Food Science and Technology* 51.11 (2012): 3269-276. Web. 23 Feb. 2017.

Contini, Claudia, Rocío Álvarez, Michael O'sullivan, Denis P. Dowling, Sean Óg Gargan, and Frank J. Monahan. "Effect of an active packaging with citrus extract on lipid oxidation and sensory quality of cooked turkey meat." *Meat Science* 96.3 (2014): 1171-176. Web. 25 Feb. 2017.

Das, Arun K., Vincent Rajkumar, and Arun K. Verma. "Bael Pulp Residue as a New Source of Antioxidant Dietary Fiber in Goat Meat Nuggets." *Journal of Food Processing and Preservation* 39.6 (2014): 1626-635. Web. 23 Feb. 2017.

Das, Arun, Vincent Rajkumar, Pramod Nanda, Pranav Chauhan, Soubhagya Pradhan, and Subhasish Biswas. "Antioxidant Efficacy of Litchi (Litchi chinensis Sonn.) Pericarp

Extract in Sheep Meat Nuggets." *Antioxidants* 5.2 (2016): 16. Web. 25 Feb. 2017.

Decker, Eric, Ryan J. Elias, and D. J. McClements. *Oxidation in foods and beverages and antioxidant applications*. Oxford: Woodhead Pub., 2010. Print.

Díaz, P., M.b. Linares, M. Egea, S.m. Auqui, and M.d. Garrido. "TBARs distillation method: Revision to minimize the interference from yellow pigments in meat products." *Meat Science* 98.4 (2014): 569-73. Web. 10 Jan. 2106.

Gotoh, Naohiro, Shino Miyake, Hiroko Takei, Kumi Sasaki, Saori Okuda, Michitaka Ishinaga, and Shun Wada. "Simple Method for Measuring the Peroxide Value in a Colored Lipid." *Food Analytical Methods* 4.4 (2011): 525-30. Web. 10 Jan. 17.

Hoffman, Louwrens C., Maxine Jones, Nina Muller, Elizabeth Joubert, and Annalene Sadie. "Lipid and protein stability and sensory evaluation of ostrich (Struthio camelus) droëwors with the addition of rooibos tea extract (Aspalathus linearis) as a natural antioxidant." *Meat Science* 96.3 (2014): 1289-296. Web. 25 Feb. 2017.

Jones, Maxine, Louwrens C. Hoffman, and Magdalena Muller. "Effect of rooibos extract (Aspalathus linearis) on lipid oxidation over time and the sensory analysis of blesbok (Damaliscus pygargus phillipsi) and springbok (Antidorcas marsupialis) droëwors." *Meat Science* 103 (2015): 54-60. Web. 25 Feb. 2017.

Karwowska, Małgorzata, and Zbigniew J. Dolatowski. "Effect of mustard on lipid oxidation in model pork meat product." *European Journal of Lipid Science and Technology* 116.3 (2014): 311-18. Web. 21 Mar. 2017.

Karwowska, Małgorzata, and Zbigniew J. Dolatowski. "Effect of mustard on lipid oxidation in model pork meat product." *European Journal of Lipid Science and Technology* 116.3 (2014): 311-18. Web. 22 Mar. 2017.

Kerry, Joseph. *Improving the sensory and nutritional quality of fresh meat*. Place of publication not identified: WOODHEAD, 2009. Print.

Kim, Y.h, K.c Nam, and D.u Ahn. "Volatile profiles, lipid oxidation and sensory characteristics of irradiated meat from different animal species." *Meat Science* 61.3 (2002): 257-65. Web. 20 Feb. 2017.

Luchsinger, S.e., D.h. Kropf, E. Chambers Iv, C.m. García Zepeda, M.c. Hunt, S.l. Stroda, M.e. Hollingsworth, J.l. Marsden, and C.l. Kastner. "Sensory Analysis of Irradiated Ground Beef Patties and Whole Muscle Beef." *Journal of Sensory Studies* 12.2 (1997): 105-26. Web. 27 Mar. 2017.

Maheswarappa, Naveena Basappa, Vaithiyanathan Subbaiah, Muthukumar Muthupalani, Praveen Kumar Yamagani, Kiran Mohan, Usha Rani Keshapaga, Shaju Vaikkathukattil Asokan, and Ramesh Chandran Kalappurakkal. "Antioxidant activity of carnosic acid and rosmarinic acid in raw and cooked ground chicken patties." *Journal of the Science of Food and Agriculture* 94.2 (2013): 273-79. Web. 25 Feb. 2017.

Modzelewska-Kapituła, Monika. "Effects of Tomato Powder on Color, Lipid Oxidation and Sensory Properties of Comminuted Meat Products." *Journal of Food Quality* 35.5 (2012): 323-30. Web. 20 Feb. 2017.

Mohamed, Hussein M.h., Hayam A. Mansour, and M. Diaa El-Din H. Farag. "The use of natural herbal extracts for improving the lipid stability and sensory characteristics of irradiated ground beef." *Meat Science* 87.1 (2011): 33-39. Web. 20 Mar. 2017.

Mohamed, Hussein M.h., and Hayam A. Mansour. "Incorporating essential oils of marjoram and rosemary in the formulation of beef patties manufactured with mechanically deboned poultry meat to improve the lipid stability and sensory attributes." *LWT - Food Science* *and Technology* 45.1 (2012): 79-87. Web. 20 Mar. 2017.

Naveena, B.m., M. Muthukumar, A.r. Sen, Y. Praveen Kumar, and M. Kiran. "Use of Cinnamaldehyde as a Potential Antioxidant in Ground Spent Hen Meat." *Journal of Food Processing and Preservation* 38.4 (2013): 1911-917. Web. 20 Jan. 2017.

O'sullivan, M.g., D.v. Byrne, H. Martens, and M. Martens. "Data Analytical Methodologies in The Development Of A Vocabulary For Evaluation Of Meat Quality." *Journal of Sensory Studies* 17.6 (2002): 539-58. Web. 27 Mar. 2017.

Ponnampalam, Eric N., Sorn Norng, Viv F. Burnett, Frank R. Dunshea, Joe L. Jacobs, and David L. Hopkins. "The Synergism of Biochemical Components Controlling Lipid Oxidation in Lamb Muscle." *Lipids* 49.8 (2014): 757-66. Web. 16 Jan. 2017.

Racanicci, Aline M. C., Bodil Helene Allesen-Holm, and Leif H. Skibsted. "Sensory evaluation of precooked chicken meat with mate (Ilex paraguariensis) added as antioxidant." *European Food Research and Technology* 229.2 (2009): 277-80. Web. 23 Feb. 2017.

Resconi, Virginia Celia, Ana Escudero, José Antonio Beltrán, José Luis Olleta, Carlos Sañudo, and María Del Mar Campo. "Color, Lipid Oxidation, Sensory Quality, and Aroma Compounds of Beef Steaks Displayed under Different Levels of Oxygen in a Modified Atmosphere Package." *Journal of Food Science* 77.1 (2011): n. pag. Web. 15 Feb. 2017.

Rhee, K.s, and C.e Myers. "Sensory properties and lipid oxidation in aerobically refrigerated cooked ground goat meat." *Meat Science* 66.1 (2004): 189-94. Web. 16 Jan. 2017.

Rhee, K.s, and C.e Myers. "Sensory properties and lipid oxidation in aerobically refrigerated cooked ground goat meat." *Meat Science* 66.1 (2004): 189-94. Web. 23 Feb. 2017.

Sampaio, G.r., T. Saldanha, R.a.m. Soares, and E.a.f.s. Torres. "Effect of natural antioxidant combinations on lipid oxidation in cooked chicken meat during refrigerated storage."

Food Chemistry 135.3 (2012): 1383-390. Web. 20 Feb. 2017.

Shahidi, Fereidoon. "Oxidative Stability and Shelf Life of Meat and Meat Products." *Oxidative stability and shelf life of foods containing oils and fats*. London, UK: Academic Press, 2016. 373-86. Print.

Simon, R. A., and H. Ishiwata. "Adverse Reactions to Food Additives." *Food Safety: Contaminants and Toxins* (n.d.): 235-70. Web. 12 Sept. 2016.

Sárraga, C., I. Carreras, J. A. García Regueiro, M. D. Guàrdia, and L. Guerrero. "Effects ofα-tocopheryl acetate andβ-carotene dietary supplementation on the antioxidant enzymes, TBARS and sensory attributes of turkey meat." *British Poultry Science* 47.6 (2006): 700-07. Web. 20 Feb. 2017.

Verma, Arun K., V. Rajkumar, Rituparna Banerjee, S. Biswas, and Arun K. Das. "Guava (*Psidium guajava* L.) Powder as an Antioxidant Dietary Fibre in Sheep Meat Nuggets." *Asian-Australasian Journal of Animal Sciences* 26.6 (2013): 886-95. Web. 23 Feb. 2017.

Warner, Kathleen, and Monoj Gupta. "Potato Chip Quality and Frying Oil Stability of High Oleic Acid Soybean Oil." *Journal of Food Science* 70.6 (2005): n. pag. Web. 4 Aug. 2016.

Yang, Han Sul, Eun Joo Lee, Sun Hee Moon, Hyun Dong Paik, Kichang Nam, and Dong U. Ahn. "Effect of garlic, onion, and their combination on the quality and sensory characteristics of irradiated raw ground beef." *Meat Science* 89.2 (2011): 202-08. Web. 20 Mar. 2017.

Zakrys, P.i., S.a. Hogan, M.g. O'Sullivan, P. Allen, and J.p. Kerry. "Effects of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere." *Meat Science* 79.4 (2008): 648-55. Web. 15 Feb. 2017.

Zakrys, P.i., M.g. O'Sullivan, P. Allen, and J.p. Kerry. "Consumer acceptability and physiochemical characteristics of modified atmosphere packed beef steaks." *Meat Science* 81.4 (2009): 720-25. Web. 15 Feb. 2017.

Šulniūtė, Vaida, Isabel Jaime, Jordi Rovira, and Petras Rimantas Venskutonis. "Rye and Wheat Bran Extracts Isolated with Pressurized Solvents Increase Oxidative Stability and Antioxidant Potential of Beef Meat Hamburgers." *Journal of Food Science* 81.2 (2016)