BOAR TAINT IN GROUND PORK PATTIES
AND PORK PRODUCTS

by

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INTRODUCTION

An undesirable boar or sex odor and flavor in pork is thought to be offensive to consumers and affects its acceptability to processors. This off odor/flavor (boar taint) has been described as onion-like, perspiration-like, and urine-like (Self, 1957). Other odors noted in boar meat volatiles are sweet, fruity, ammonia-like, and animal-like (Griffiths and Patterson, 1970).

Williams et al. (1963) found sex odor in 64% of boars weighing 180-240 lbs. It also has been found in sows and gilts, although with less frequency (Beery and Sink, 1971). When boar taint is found, consideration must be given as to what can be done with the boar carcass.

The purpose of this study is to further identify flavor and odor characteristics associated with boar meat and to develop a product in which the tainted meat could be used satisfactorily. Because boars develop faster and produce a leaner meat than their counterparts, this study has widespread relevance for producers as well as consumers. Consumers today are more health conscious, and leaner meat fits into their lifestyle, while producers would benefit from shorter growing times by having less money and time invested from farrow to finish.

REVIEW OF LITERATURE

Meat Flavors

Meat flavor can be divided into three major categories (Brennand, 1983). General broth-like flavor is common in all red meats, regardless of source, and could be represented by boiled lean meat. A second category includes flavor components that are associated with identification of a specific meat (i.e., beef, rather than lamb). A third category of meat flavor is dependent on the method of cooking, since dry heat produces a different flavor than moist heat cookery methods (Brennand, 1983).

Despite a number of studies in recent years (Wasserman and Spinelli, 1972; Sink, 1973; Gorbatov and Lyaskovskaya, 1980; Brennand and Lindsay, 1982), specific components responsible for meat flavor and odor or the site of the developing flavor have not been identified.

Over 300 volatile compounds have been identified in meat, all of which are potentially important to the flavor of meat (Brennand, 1983). Problems in identifying species-specific flavor compounds are that the flavor may be due to the presence of specific compound(s), the exact concentration of the compound(s), or to an interrelationship among the constituents (Brennand, 1983). A problem that may occur during isolation of specific compounds is that the compound will change its character during the isolation process.

Pork Flavor

Raw meat has a weak, salty-sweetish taste that changes to the characteristic flavor of the specific meat during culinary or technological processing (Gorbatov and Lyaskovskaya, 1980). Identification of 179 components was reported for the flavor of pork liver by Mussinan and Walradt (1974). Gorbatov and Lyaskovskaya (1980), Cross and Ziegler (1965), Lillard and Ayres (1969), and Ockerman et al. (1964) have identified 40 carbonyls, aldehydes C_1 - C_{10} and C_{12}, and acetone in raw, cooked, and cured pork flavor. No single constituent was identified as responsible for the species-specific flavor of pork.

Hornstein and Crowe (1960; 1963) reported that lean portions of beef, pork, and lamb contribute a meaty, non-specific flavor. Flavor differences between beef and pork appear to originate in the fat, as suggested by Hornstein and Crowe (1960), Wasserman and Talley (1968), and supported by findings of Brennand and Lindsay (1982).

Off-Odors Associated with Pork

Odor characteristics by which pork is recognized are not always the aromas associated with pork chops or other pork cuts. Many times off-odors or aromas are identified as piggy, sour or goaty (Wasserman and Spinelli, 1972), as well as the long recognized swine sex odor (SSO) that is associated or found most commonly in meat from intact male pigs (boars). The SSO also has been found in some female hogs, and hogs that were small, thick-skinned, low in fat and retarded in development (Self, 1957).

Boar Taint. The volatile compounds contributing to swine sex odor, boar taint, or boar odor have received attention over the years (Sink, 1973). First attempts to identify the specific chemical compound responsible for boar taint began with Lerche in 1936 (Brooks and Pearson, 1986). Lerche demonstrated that the unpleasant odor of heated boar meat first became apparent at the onset of sexual maturity and disappeared following castration. Prelog and Ruzicka (1944) first isolated C_{19}-delta^{16}-steroids from boar testes, which they described as having musk-like odors. Craig and Pearson (1959) and Craig et al. (1962) conducted additional research on the chemical compounds responsible for boar odor. They established that the undesirable "urine-like" or "perspiration-like" odor was associated with the adipose tissue and was concentrated in the non-saponifiable fraction of the fat. Patterson (1968) reported the presence of 5 alpha-androst-16-ene-3-one in the high vacuum volatile strippings from boar fat, and identified this as the "perspiration-like" constituent of boar odor. Other researchers (Beery and Sink, 1971; Beery et al., 1971; Thompson et al., 1972) confirmed this finding and identified other C_{19}-delta^{16} steroids (5 alpha-androst-16-en-3 alpha-ol and 5 alpha-androst-16-en-3 beta-ol) as contributors to boar odor. Skatole, a compound possessing a strong fecal odor was isolated from the steam distillate of boar fat by Vold in 1970 as well as Walstra and Maarse in 1970, according to Brooks and Pearson (1986). Skatole, a metabolite formed during the breakdown of tryptophan by intestinal microorganisms, has been found to strengthen synergistically the unpleasant odor of 5 alpha-androst-16-ene-3-one (Lundstrom et al., 1980). However, Hansson et al. (1980) found that skatole was not specific for boar fat since similar skatole concentrations were found in barrow and gilt fat.

Methods for Identifying Boar Taint

Physical Measurements. Attempts to develop methods for successfully identifying boar taint, before or at the time of slaughter, would provide an effective method of screening out "tainted" carcasses. The primary focus of these methods are: ease of obtaining quick results, reliability, and inexpensiveness (Bonneau and Russeil, 1985). The earliest reported method of detecting taint or sex odor in pork was developed by Jarmoluk et al. (1970). It is based on the principle of volatilizing compounds responsible for odor and flavor contained in pork, such as those that would occur during the cooking process, by use of a 115-volt pistol-grip electric soldering gun (with continuous heat build-up). The tip of the gun is applied to a fat sample of the carcass or pork cut, which releases aromas observed in the cooking process. One individual with extensive previous experience in rating aromas of cooked pork would be responsible for testing all samples. As Bonneau and Desmoulin (1975) reported though, this method was not reliable for normal slaughterhouse conditions because of its subjectivity and dependence on previous experience. Therefore, work has proceeded on developing more objective instrumental methods by which boar odor can be evaluated.

Forland et al. (1980) studied the relationship between the size of accessory sex glands in boars, androstenone levels in fat, and intensity of boar odor. They concluded that the size of accessory sex glands gave an indication of the level of androstenone in the fat. Boars with large accessory glands had high concentrations of androstenone ($r = 0.56 - 0.75$). Correlation also was determined between size of the glands and intensity of boar odor ($r = 0.28 - 0.34$). Forland et al. (1980) postulated that the lower r values for gland size vs. boar odor intensity partially could be because of the difficulty of subjectively evaluating boar taint, but also suggests that factors or compounds contribute to boar taint other than androstenone. This theory is supported in findings by Malmfors et al. (1978) who reported low correlations ($r = 0.43 - 0.66$) between androstenone levels in fat and intensity of boar taint. However, in 1981, Bonneau and

Desmoulin (Bonneau and Russeil, 1985) reported a close correlation between the size of accessory sex glands (Cowpers gland [Bulbo-urethral]) and boar taint intensity as assessed by a laboratory panel. Apparently, further work is warranted in this area.

Instrumental methods for determining boar taint are available, but are limited by excessive time consumption or expense. They do appear, however, to be more reliable than previous methods discussed.

Early work by Patterson (1968), Beery and Sink (1971), and Thompson et al. (1972) involved using thin layer chromatography for purification of samples prior to gas chromatograph-mass spectrometry for component identification. Claus et al. (1971) also employed the use of expensive radioisotopes in gas chromatographic analyses. Radio-immunoassays for detecting 5 alpha-androst-16-ene-3-one in adipose tissue and blood plasma were developed by Andresen (1974), and used by subsequent researchers (Brooks and Pearson, 1986). While radio-immunoassay is faster and more sensitive than gas chromatography-mass spectrometry, it is also more costly and involves the use of potentially hazardous radioactive materials (Brooks and Pearson, 1986).

Thompson and Pearson (1977) developed a method for quantitative determination of the C_{19}-delta^{16}-steroids that utilizes a deuterium isotope dilution carrier technique as an internal standard, and employs selected ion monitoring gas chromatography-mass spectrometry for detection. No radioactive materials are used for this method, and it has comparable sensitivity to the radio-immunoassay technique. The disadvantage of this method is the time consuming sample preparation and need for highly sophisticated gas chromatography-mass spectrometry equipment.

One of the newest methods available for identification of C_{19}-delta^{16}-steroids is the enzyme-linked-immuno-absorbant-assay (ELISA). This method is based on competition between unlabelled C_{19}-delta^{16}-steroids in the sample and a standardized amount of added "labelled" C_{19}-delta^{16}-steroids for specific binding sites on antibody molecules in purified antisera (Brooks and Pearson, 1986). The "labelled" steroid consists of a C_{19}-delta^{16}-steroid enzyme conjugate that remains active after conjugation and binding to the antibody site. Enzyme activity of the sample can be measured by adding the appropriate enzyme substrate, and quantitatively measuring the resulting color, chromophore or fluorescence and comparing to standard titration curves. This method's speed, accuracy, sensitivity, and reliability have not been substantiated in the literature (Brooks and Pearson, 1986).

Sensory Analysis. The last, but perhaps most important means of evaluating boar taint, is measurement by sensory analysis. The primary consideration of boar odor or taint is the fact that when humans detect this odor during the cooking process, many find it objectionable and reject the meat.

An early sensory study by Griffiths and Patterson (1970) tested 301 panelists by application of 800 μg of androstenone (in solution with diethyl ether) to a 5cm^2 area of a watch glass. Of the 301 panelists (156 males, 145 females) screened, 44.3% of men were unable to detect boar odor, while only 7.6% of women tested could not detect it. Panelists who could detect boar odor were asked to give hedonic ratings (on a scale of 1 = extremely pleasant to 9 = extremely unpleasant), and women found the smell significantly more unpleasant than men. During this study, terms used to describe the odor were animal, sweaty, urine, or ammonia-like, with the terms sweet, fruity or perfume-like included.

Flavor profile work by Gardze et al. (1979) utilizing loin roasts also found that animal-like aroma and flavor was stronger in boar and barrow meat, than in gilt and ovariectomized gilt samples. Panelists described the animal aroma note for boars as more intense than for the barrow, but the barrow had a slightly stronger cooked pork flavor than the boar. Other aroma and flavor notes included by this profile for boar taint were "sharp disagreeable nosetingle", chicken, sour, metallic, mouthfilling, monosodium glutamate, old meat and mouthcoating.

Consumer Reaction to Boar Taint

Consumer tests conducted during the past 15 years regarding acceptability of boar meat have had varying results using hedonic scales. Variation appears to be dependent on country of origin (of the study), and variation in design of experiments, among other factors.

Pearson et al. (1971) reported favorable results in studies using processed pork products with a 60-member consumer panel. They found that products containing boar meat were not readily distinguishable from similar control (containing no boar odor) products, particularly if consumed without heating. Rhodes (1972) reported no significant detection and rejection of the boar product in pork joints when 419 households (1560 persons) were surveyed, although 10% of the consumers marked the product as "less pleasant than normal". Further work by Rhodes and Krylow (1976) also showed no evidence of impaired acceptability by the 47 cooks in the kitchen or consumers (156 family members) of sausages made from boar tainted pork. In fact, boar sausages were judged to have better flavor than normal, significantly more so than the control product. Lesser et al. (1977) found no significant differences between the distribution of consumer scores for bacon from intact and castrated males. Scores averaged slightly higher for boars in most cases, and the conclusion was made to market bacon from uncastrated boars.

Quite different results have been reported from France by Desmoulin et al. (1982). Consumer acceptability of pork from boars was much lower than in previously reported studies, particularly for cooking odor, which was rated unpleasant in more than one third of boar roasts and cutlets tested. They attributed these results to differences in culinary habits and/or to higher frequency and intensity of taint in the older, more mature boars used in the experiment.

Processing reduced differences in scores between boar and control samples. Overall acceptability of processed products from control pigs was only slightly higher than products produced from boar meat (Desmoulin et al., 1982). This study also attempted to determine if fat levels of androstenone in boars coincided with consumer opinion. Boars were divided into 3 groups of androstenone levels; less than 0.5μg g^{-1}, between 0.5μg g^{-1} and 1μg g^{-1}, and greater than 1μg g^{-1}. Percentages of unpleasant ratings of cooking odor were much higher in boars than in controls, even for the lowest androstenone grouping (Desmoulin et al., 1982). The higher the androstenone levels, the higher the percentage of unfavorable opinions. Percentages of unpleasant ratings of flavor tended to increase with higher androstenone levels, although they were not significant (Desmoulin et al., 1982).

As mentioned previously, processed pork products received only slightly lower acceptability scores than control products. Improvement of consumer acceptability of processed products is thought to be because of two reasons: 1) androstenone partly disappears from fat during processing (Desmoulin et al., 1982), and 2) consumption of cold hams and sausages tends to minimize odor release, and spices added to the mixture may mask unpleasant flavors (Desmoulin et al., 1982). Because of these effects, these researchers concluded that only boar meat with high levels of androstenone would be unacceptable to consumers, and the highly tainted meat could possibly be used if diluted with untainted meat.

A Swedish study conducted by Lundstrom et al. (1982) agreed with the investigation by Desmoulin et al. (1982). Up to 20% uninformed Swedish consumers reacted more critically to boar odor in fresh pork cutlets, while up to 35% of informed consumers reacted critically to boar odor, compared to 5-10% negative reactions for the control meat. Consumers who were informed they were testing boar meat reacted, on the whole, more critically than the uninformed consumers (Lundstrom et al., 1982). This led to the conclusion that if boar meat is to be introduced into the market, consumer education will be necessary, with a great deal of attention given to the type of information published. The studies indicated further research should be directed at finding a reliable screening test for sorting out tainted boar carcasses (Lundstrom et al., 1982; Desmoulin et al., 1982).

Methods for Preventing Boar Taint Development

Presently, the accepted and standard practice for preventing boar odor or taint is castration of all male pigs intended for meat production. While this method is effective, it is labor intensive and time consuming, involves the risk of infection, and slows growth of the pig (Brooks and Pearson, 1986). Rearing of boars rather than barrows would result in production of 8-10% more lean meat per pig, and in addition, would increase feed efficiency by 12-15% (Pearson, unpublished data in Brooks and Pearson, 1986).

Early studies by Plimpton et al. (1971) indicated that the subcutaneous implantation of 96 mg of diethylstilbestrol in boars significantly reduced boar odor and flavor scores, and the effect of the treatment lasted for at least 10 weeks. This work was substantiated by Newell et al. (1973), although little follow-up work has been done with this compound.

Other chemical agents that appear promising include 5 alpha-pregnane-3,20-dione, which inhibits the andien-beta synthetase system, through which 5 alpha-androst-16-ene-3-one is synthesized (Brophy and Gower, 1974). However, this compound also inhibits formation of androgenic and estrogenic sex hormones which are necessary for normal development, and further work needs to be done (Brooks and Pearson, 1986).

Williamson et al. (1985) and Williamson and Patterson, (1982) studied the feasibility of autoimmunization against 5 alpha-androst-16-ene-3-one in boars, with promising results. They report that autoimmunization effectively reduced the amount of androstenone found in adipose tissue, although complete suppression was not obtained and suggested further work be done. Sensory evaluation of meat or fat samples was not done in this study, making it impossible to draw conclusions regarding this method.

MATERIALS AND METHODS

This study was divided into two parts: 1) flavor profile attribute analysis of pork patties made from fresh ground pork or ground pork that was known to have a boar taint, and 2) developing prototypes of products that could successfully mask boar taint through the use of sensory analysis.

Standardization of Ground Pork

Meat for the entire study was obtained from the Department of Animal Science and Industry, Kansas State University. Shoulders and picnics from hogs previously identified as having boar taint were used as "boar meat", and control shoulders and picnics were used for the "fresh pork" samples. Meat was coarsely ground through a 13mm (1/2") plate, and then ground through a 3mm (1/8") plate. All ground meat was standardized to contain 20% fat. It was portioned into approximately 454g (1 lb) blocks, single wrapped in heavy, wax-coated butcher paper, and frozen immediately at -25°C for the duration of the study.

Part One

Panelist Training

The study utilized trained professional panelists from the Sensory Center, Department of Foods and Nutrition, at Kansas State University. In the initial phase, training sessions were conducted where the panelists familiarized themselves with the samples and agreed on common terminology. From these sessions, a score card was developed. References were identified for specific odor and flavor characteristics, when necessary. The reference for pungent was burned butter, because of the acrid smell of acrolein. A dilute solution of ammonia-water served as the reference for ammonia-like. No reference for musty was needed, because of panelist agreement and previous experience. Intensity of identified attributes for aroma (or odor) characteristics of musty, pungent and ammonia-like, and flavor components of juicy, sweet, musty and ammonia-like were scored on a semi-structured linear scale (Figure 1, Appendix). Sensory data were converted to numerical values by measuring the 15-cm line from the left anchor (low intensity) to the point on the scale where the panelist had made a perpendicular mark. This score card was used for the first portion of the study. When the initial training was completed, data collection commenced.

Preparation of Ground Pork Patties

Pork samples for evaluation were prepared in the following manner. The ground meat was removed from freezer storage late in the afternoon (4:00 p.m. - 5:00 p.m.) and placed in a refrigerator (4 - 7°C) overnight to thaw for use the following morning. Portions of 78g were weighed and shaped into standard-size 90mm (3-1/2 in) diameter patties, using a plastic meat patty press. Three patties were then placed on a broiler pan and broiled 4 minutes per side, removed, weighed and cut into 6 triangular-shaped pieces.

Presentation of Samples to Panelists

Three triangular-shaped pieces were placed in each prewarmed 90mm (3-1/2 in) glass custard cup and covered with a watch glass. Temperature of samples was maintained by placing custard cups on a Maxim warming tray, Model WT48, set on III ("high" setting). Two samples of ground pork, in covered custard cups, one of each type, were presented to each panelist in randomized order for evaluation of specified odor characteristics and then flavor attributes. Six trained panelists participated in the study for four panel sessions.

Physical Measurements

Cooking losses, pH, and expressible moisture also were determined at the time of sample preparation.

Cooking losses. Total cooking losses, as well as those attributed to drip and evaporation, were determined by the method outlined by Campbell et al. (1979).

pH. All pH determinations were obtained by preparing a slurry of meat and water. A 1:10 slurry was prepared by combining 5g meat (raw or cooked) with 50ml distilled water at room temperature, blending for 10 seconds on medium speed in an Osterizer blender. The slurry was poured into a 50 ml beaker, and a magnetic stirrer was used at a medium speed to maintain homogenity. The pH readings were taken from the center of the beaker, with a Horizon Ecology Co. pH meter, Model 5998-10. Duplicate samples were prepared for pH measurements.

Expressible moisture. Expressible moisture was determined using the Carver press method outlined by Miller and Harrison (1965). A 0.3g sample of ground pork was placed on Whatman #1 filter paper, then between two Plexiglass sheets. Pressure was applied to duplicate samples for 5 minutes at 3000 lbs. A compensating polar planimeter was used to obtain readings of the area of the original sample and the moisture expressed. Expressible moisture was calculated as:

$$\%\ \text{Expressible moisture} = \frac{\text{Area of moisture expressed} - \text{Area of original sample}}{\text{Area of moisture expressed}} \times 100$$

Part Two

Panelist Training

Three panelists from the first part of the study were selected to continue in part two, based on statistical analysis of their performance in part one. Panelists refamiliarized themselves with both types of meat. Based on the attributes identified during profile attribute analysis, a scorecard similar to the one used in the first part of the study was developed (Figure 2, Appendix). It was determined that the terms juicy and sweet would no longer be relevant because of the additional ingredients that would be added during prototype development. However, the remaining terms of musty, pungent, and amonia-like were identified as the components with greatest intensity in boar-tainted meat which influence acceptance or rejection by consumers.

Prototype Development

The second half of the study consisted of developing a commercial prototype that had potential for consumer acceptance. In order to accomplish this, it was determined that undesirable off-aromas and off-flavors identified in Part 1 of the study must be minimized or undetectable to the three expert panelists chosen to continue the study.

In considering potential products to screen, it was determined that tomato-based products with added spices offered the best potential of masking boar-tainted meat. It was hypothesized that the acidic pH of tomato-based products would neutralize the ammonia-like odor and flavor. Because of the limited amount of boar-tainted meat that could be obtained for the study and the high degree of sensitivity and reliability of the panelists chosen to continue, the decision also was made to limit screening of each product to one replication.

The first commercial product attempted was pizza. With the popularity of pizza growing appreciably, this would be a logical and profitable outlet. Chef Boyardee crust and sauce were used, as well as Martha White crust mix and Ragu Pizza sauce. Crusts were prepared according to package directions. They were patted out to approximately 1/4" thickness on baking pans in approximately 15cm X 20cm (6" X 8") rectangles, and covered with 60g (2 oz) of each sauce. Ground meat (100% boar tainted pork or 100% control pork) was browned, crumbled and drained. Browned meat (120g or 4 oz) was then sprinkled on the prepared crusts with sauce and baked at 232°C (450°F) for 12-15 minutes.

Immediately upon removal from the oven, the crust edges were removed and rectangular pieces cut for sample presentation. Samples were placed in pre-warmed custard cups, covered with watch glasses and evaluated as a whole.

Panelists were instructed to taste crust, sauce and pork in each bite. Panelists were able to readily identify the boar tainted pork samples (Table A-1, Appendix).

The second product tried was spaghetti sauce. Again the meat was browned, crumbled, drained and the respective meats were added (in the recommended amounts) to two different commercially prepared sauces. Prego original recipe and Ragu original were the sauces used. Spaghetti sauce samples containing ground pork were presented to the panelists in pre-warmed custard cups (100% pork and 100% boar tainted meat were the two variables). Preliminary screening again indicated that the spice profile of the sauces was unable to mask the boar odor and flavor (Table A-2, Appendix).

The third product screened was chili seasoning. The samples were prepared by browning and crumbling the meat (227g), draining and adding 118 ml of water plus the spice packet to the meat. Initially, 100% control pork and 100% boar meat were used with Lawry's and McCormick's chili seasoning mixes. After adding the water and spices to the meat, the mixture was allowed to simmer for 3-5 minutes before being portioned into pre-warmed custard cups and covered with watch glasses. Samples were evaluated by the panelists and they determined that the flavor profile of the spices found in the chili seasoning mixes had the greatest potential for masking the boar taint (Table A-3, Appendix). Many of the spices contained in the chili seasoning packet (particularly the cumin), contain some of the same musty and pungent odor and flavor characteristics that were described as typical of boar odor and flavor. These shared characteristics seemed to maximize chili seasoning's ability to mask boar taint.

Based on these studies, it was determined to continue work with the chili product using the Lawry's seasoning mix. Panelists were able to identify boar taint at the 100% boar meat level. Therefore, the next step was to vary the levels of boar meat with the control ground pork. After several trials, it was determined to use the following combinations of boar meat and control pork (% boar : % control): 30 : 70:, 20 : 80, 15 : 85, and 10 : 90 with intensity scoring (Figure 3, Appendix). As a means of checking panelist reliability and consistency, 100% boar and 100% control pork samples also were included in the trials.

Experimental Design and Statistical Analysis

A randomized complete block design was used for Part 1 of the study with five replications. All instumental and sensory data were subjected to analysis of variance. Means were compared and differences, when found, were separated using Fishers Protected Least Significant Differences procedures. Analysis of variance for Part 1 of the study was as follows:

Source of variance	df
Replication (Rep)	4
Pork type (Ptype)	1
Panelist	3
Rep x Ptype	4
Ptype x Panelist	3
Error	24
	39

A randomized complete block design with six replications was used for Part 2 of the study. Analysis of variance for Part 2 of the study was as follows:

Source of variance	df
Group (Panelist)	2
Replication (Rep)	5
Group x Rep	10
Treatment (Trt)	5
Error	85
	107

RESULTS AND DISCUSSION

Physical Measurements

Data for expressible moisture, pH and percentage cooking losses are reported in Tables 1 and 2. Although no significant differences were observed in expressible moisture between control and boar patties, the boar meat tended to have higher expressible moisture values, indicating a higher water holding capacity WHC. This observation was supported by the raw pH values, where differences were found between the two meats. The higher the ultimate pH of raw meat (post-mortem), the greater the WHC (Lawrie, 1974). Higher pH values obtained for cooked patties are to be expected. The chemical changes that meat undergoes during the cooking process causes a loss of free acidic groups and WHC, as well as a rise in pH (Lawrie, 1974).

Values obtained for cooking losses also are supported by the previous measurements discussed. The boar meat had lower evaporative and drip losses than the control pork. As Lawrie (1974) reports, if pork muscle is below pH 5.9, cooking losses usually are greater than if pH is above 6.0. Although pH values for both meats were below 5.9, it is reasonable to assume that as pH continues to drop farther below pH 5.9, cooking losses will continue to increase.

Sensory Characteristics

Mean sensory values for ground pork patties are reported in Table 3. Differences in juiciness are expected, as previously discussed and supported by physical measurements for expressible moisture, percentage cooking losses, and

Table 1. F-values and probabilities[a] from ANOV for physical measurements of ground pork patties.

Physical measurement		
Expressible moisture	2.22	(0.2102)
pH		
Raw	13.16	(0.0222)
Cooked	1.28	(0.3218)
Cooking losses		
Evaporative	0.61	(ns)
Drip	5.58	(ns)
Total	2.76	(ns)

[a] p values are in parentheses.

Table 2. Mean[a] values for physical measurements for ground pork patties made from control and boar meat

Physical measurement	Pork type: Control	Pork type: Boar
Expressible moisture (%)	47.30a	51.64a
pH		
Raw	5.80a	5.85b
Cooked	6.02a	6.05a
Cooking losses (%)		
Evaporative	22.49a	20.37a
Drip	10.73a	8.63a
Total	33.21a	28.99a

[a] Means with the same letter in a row are not significantly different ($p \leq 0.05$); each value represents a mean for five replications with two measurements per treatment for a total of 10 observations per mean.

Table 3. F-values and probabilities[a] from ANOV for sensory characteristics of ground pork patties made from control and boar meat

	Odor characteristics			Flavor characteristics			
	Musty	Pungent	Ammonia-like	Juicy	Sweet	Musty	Ammonia-like
	17.35 (0.0141)a	18.04 (0.0132)	31.32 (0.0050)	15.32 (0.0173)	0.96 (0.3835)	17.59 (0.0138)	27.01 (0.0065)
Error[b]	4.41b	6.66	8.08	1.43	3.89	6.40	9.52

[a] p values are in parentheses.

[b] Error mean squares used in comparing pork types.

Table 4. Mean[a] sensory values for odor and flavor characteristics of ground pork patties made from control and boar meat.

Sensory parameters	Pork type	
	Control	Boar
Odor characteristics		
Musty	6.06b	8.82a
Pungent	5.47b	8.93a
Ammonia-like	3.98b	9.02a
Flavor characteristics		
Juicy	6.42b	7.90a
Sweet	5.55a	6.16a
Musty	5.48b	8.84a
Ammonia-like	3.23b	8.30a

[a] Means with the same letter in a row are not significantly different ($p \leq 0.05$), each value represents a mean for five replications with four panelists per treatment for a total of 20 observations per mean.

pH. Because fat content of the ground pork was standardized to 20% at the time of grinding and packaging, differences should not be attributable to this factor. No differences were found in sweetness between patties from the two meats, but for all other characteristics, significant differences were found ($p < 0.05$). These findings are well documented in the literature, beginning with Craig and Pearson (1959) and Craig et al. (1962) who established the presence of "urine-like" or "perspiration-like" odor found in boar fat which would relate to the pungent and ammonia-like terms used in this study. Flavor profile results by Gardze et al. (1979) also found a "disagreeable nosetingle", which agrees with the findings of pungent and ammonia-like. Other terms reported by Gardze et al. (1979) include animal-like aroma and flavor that received higher intensity scores in boar loin roasts, which also relate to the musty term used in this study.

Effect of type of pork with chili seasoning

F-values and probabilities for sensory characteristics of ground pork with chili seasoning are reported in Table 5. F-values for the odor characteristic musty showed no significant difference (regardless of the percentage of boar meat used with control.) This finding is believed to be related to the spices contained in the chili seasoning mix, which according to the label statement included: chili pepper and other spices, wheat flour, onion, salt, and garlic. Other spices in chili seasoning usually include cumin (or cominos), which is a hot, bitter and strongly aromatic component of chili powders (Bennion, 1985). Cumin also has been described as having a musty odor and flavor, which may have masked the musty odor component found in boar meat previously. Differences were found for all other odor and flavor characteristics, with mean values and LSD's reported in

Table 5. F-values and probabilities[a] from ANOV for sensory characteristics of ground pork with chili seasoning

Odor characteristics			Flavor characteristics	
Musty	Pungent	Ammonia-like	Musty	Ammonia-like
1.63 (0.1608)	3.72 (0.0044)	3.25 (0.0099)	2.37 (0.0455)	4.06 (0.0024)

[a] p values are in parentheses.

Table 6. For all sensory characteristics, no differences were found between the 100% boar samples and samples containing 30 boar : 70 control pork. Although some differences exist between treatments and some sensory characteristics, no significant differences were found among the 20% boar, 15% boar, 10% boar and 100% control pork samples. For the musty flavor characteristic the F-value was low, indicating less difference in mustiness among samples than in the other characteristics, which again could be a result of the seasoning blend utilized. Since professional sensory panelists were unable to detect differences in odor and flavor characteristics when 20% or less boar meat was used with chili seasoning, it is unlikely that consumers could detect presence of boar meat at these levels.

Table 6. Mean[a] sensory values for ground pork with chili seasoning

Treatments (% Boar : % Control)	Odor characteristics		Flavor characteristics	
	Pungent	Ammonia-like	Musty	Ammonia-like
100 : 0	7.661a	7.6278a	6.9556a,b	6.91a
30 : 70	6.6583a,b	6.8556a,b	7.1667a	6.5167a,b
20 : 80	4.1667c	4.4144c	5.025c	3.4056c
15 : 85	4.6261b,c	5.1944b,c	5.75a,b,c	4.3056b,c
10 : 90	4.700b,c	5.0917b,c	5.19c	3.1306c
0 : 100	4.1667c	3.9528c	5.29b,c	3.1056c

[a] Means with the same letter in a column are not significantly different ($p \leq 0.05$); each value represents a mean for six replications with three panelists per treatment for a total of 18 observations per mean.

CONCLUSIONS

Based on the conditions of this study, it can be concluded that boar tainted pork possesses a strong musty, pungent and ammonia-like odor, and pungent and ammonia-like flavor in ground pork patties. These undesirable odor and flavor characteristics can be masked by using chili seasonings and varying the proportions of boar tainted meat vs. control pork. Up to 20% boar tainted pork was used with chili spices without detection by a trained professional sensory panel. Therefore, use of boar meat at levels of 20% or less has potential for consumer acceptance.

Further work is warranted to 1) determine if the spice blends used in preparation of similar foods could successfully mask boar taint; 2) investigate feasibility of industrial application of findings in the current study; and 3) determine acceptance/preference of these findings at the consumer level.

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APPENDIX

Figure 1. Scorecard for patties containing control or boar-tainted pork.

NAME______________________________ DATE____________________________

A reference sample has been provided for you; please smell, then taste it first. After you are finished with the reference sample, please do not return to it. Flip the penny provided for you. If "heads" appears first, taste sample ________. If "tails" appears first, taste sample ________. Then taste the remaining sample. Place a line perpendicular to the scored line at the point which best describes your evaluation for the attribute listed. Label each mark with the sample number. Please circle which sample you tasted first.

ODOR

Musty

Low High

Pungent

Low High

Ammonia like

Low High

FLAVOR

Juicy

Low High

Sweet

Low High

Musty

Low High

Ammonia like

Low High

Figure 2. Scorecard for control or boar-tainted pork with chili seasoning.

NAME________________________________ DATE________________________________

Please smell, then taste the samples in order, from left to right. Place a line perpendicular to the scored line which best describes your evaluation for the attribute listed. Label each mark with the sample number. Thank You!

ODOR

Musty

Low High

Pungent

Low High

Ammonia like

Low High

FLAVOR

Musty

Low High

Ammonia like

Low High

Table A-1. Ranges of scores and comments for pizza made with control ground pork and boar-tainted ground pork.

Pizza made with control ground pork		
Odor	Range of Scores	Comments
Musty	2-5	-low musty
Pungent	4-5	-tomato pungent
Ammonia-like	0-1	-no off odor
Flavor		
Musty	1-2	
Ammonia-like	0-1	

Pizza made with boar-tainted pork		
Odor	Range of Scores	Comments
Musty	6-9	-Pungent, both boar and tomato
Pungent	6-10	
Ammonia-like	6-8	
Flavor		
Musty	7-8	
Pungent	7-8	

Table A-2. Ranges of scores and comments for spaghetti sauce made with control ground pork and boar-tainted ground pork.

Spaghetti sauce with control ground pork		
Odor	Range of Scores	Comments
Musty	2-3	-sauce masked the meat
Pungent	1	-oregano is "key" cover
Ammonia-like	0	
Flavor		
Musty	1-2	-no off flavors
Ammonia-like	0-1	-mild and pleasing

Spaghetti sauce with boar-tainted ground pork		
Odor	Range of Scores	Comments
Musty	5-8	-could smell the meat; not masked by sauce.
Pungent	3-7	
Ammonia-like	4-8	
Flavor		
Musty	5-7	
Ammonia-like	5-9	

Table A-3. Ranges of scores and comments for chili seasoning with control ground pork and boar-tainted ground pork.

Chili with control pork		
Odor	Range of Scores	Comments
Musty	5-6	-musty, sharp spices of chili seasoning have potential for better cover up than other products screened
Pungent	2-5	
Ammonia-like	0	
Flavor		
Musty	3-5	-sauce notes strongest
Ammonia-like	0-4	

Chili with boar-tainted ground pork		
Odor	Range of Scores	Comments
Musty	7-9	-spicy, sweet flavor from sauce
Pungent	7-8	-this spice blends and covers better
Ammonia-like	7-9	
Flavor		
Musty	8-9	
Ammonia-like	8-9	

BOAR TAINT IN GROUND PORK PATTIES AND PORK PRODUCTS

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Expressible moisture, raw and cooked pH, cooking losses and sensory characteristics for ground pork patties containing control pork and boar tainted pork were evaluated. No differences were found between the two meats in expressible moisture, cooked pH or cooking losses, but raw pH values were higher for boar patties than for control patties ($p \leq 0.05$). Sensory analysis revealed no differences in sweetness, but significant differences were observed for the odor characteristics of musty, pungent and ammonia-like, as well as flavor characteristics of juiciness, musty and ammonia-like ($p \leq 0.05$).

Chili seasoning was used to mask boar taint with various proportions of boar to control ground pork. No differences were found in sensory characteristics mustiness, and at levels of 20% boar meat or less, no significant differences were observed for pungent and ammonia-like odor, or musty and ammonia-like flavor. Characteristics associated with boar taint consistently were scored higher in intensity when levels of 30% boar meat or greater were used.