UNIVERSITÀ DEGLI STUDI DI PADOVA

Department of Land, Environment Agriculture and Forestry (TESAF)

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Survey of various meat quality parameters to determine the meat quality of Husum saddleback pigs

Supervisor

Prof. Andrea Laconi

Co-supervisor

Prof. Katharina Riehn

Submitted by

Sina Kordzadeh

Student no. 2040409

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I sincerely thank my mother and my brother for always believing in me and for their infinite support. I dedicate this work to the soul of my father, whose guidance and love continue to inspire me every day. To the friends I made during these years, you made me rethink my beliefs and experience emotions and events I could have never imagined. Finally, to myself, with the hope for the future, to learn to believe more in my capabilities.

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1. Abstract

Pork is the second most popular meat worldwide and is expected to continue to grow, making it even more important to improve the quality of meat, particularly in specialty breeds like the Husum saddleback pig. The primary criteria of meat quality that are important for sensory qualities including flavor, tenderness, juiciness, and also nutritional value are the ultimate pH (UPH), protein content, meat color, and intramuscular fat (IMF). These factors are examined in this thesis. Although Husum saddleback pigs have less muscular mass than other breeds, our extensive research shows that they have a greater IMF content, which improves the quality of their meat. The study emphasizes how feeding practices have a major impact on the quality of meat and how balanced meals full of vital nutrients are necessary to satisfy sustainable requirements for meat production. As demonstrated by substantial group differences using one-way ANOVA ($F=64.17$, $p=0.000$, R-squared=98.41%) and Tukey pairwise comparisons, IMF is essential in determining taste, tenderness, and juiciness. While Group N (PERSA Sch. EOEKA HS2) had the lowest mean IMF (0.155), appropriate for lean meat tastes, Group A (Bio, PVC 048, Schl 26) displayed the greatest mean IMF (6.175 and 5.53, respectively), suggesting excellent meat quality. Using the RM200QC and CM-5 Konica spectrophotometer, the color evaluation revealed notable differences across the groups as well, with higher mean values corresponding to perceived quality. Groups with different protein levels were detected by protein content analysis ($F=2.72$, $p=0.003$), with PVC 043, and Schl 25 showing the highest mean (28.43). The mean pH levels of the feeding groups varied significantly ($p=0.000$), with Group A (Bio) recording the highest pH (mean=6.175) and Group C (Sch. EOEKA) the lowest (mean=5.585). Higher pH levels are indicative of better meat quality and longer shelf life. The results support pricing schemes that take into account the better meat quality of Husum saddleback pigs, supporting sustainability in organic and ecological agricultural environments. To improve knowledge and application in the meat business, future research should focus on longitudinal studies on feeding schedules, selective breeding, customer preferences, and post-slaughter procedures. Overall, this study opens the door for future research and practical applications in sustainable hog production by offering significant insights into the meat quality of Husum saddleback pigs.

2. Introduction

Pork ranks as the second most consumed meat globally, with expectations pointing towards a steady expansion in its production in the coming years (Alfaia et al., 2019). Saddle pigs are said to have characteristics that make them particularly interesting for extensive housing systems, the use of local feed, and further developed forms of housing in conventional agriculture (more freedom of movement, especially for the sows). The preservation of the old genetics and the examination of the special characteristics are therefore of great interest. The Angler saddle pig is a breed of pig native to Schleswig-Holstein that has been threatened for decades due to its small population size. The closely related German saddle pig, which is particularly widespread in the eastern federal states, is also threatened. If a breed becomes extinct, animal genetic resources and thus genetic diversity are lost, which could possibly be of importance in the future under changing conditions (e.g. infectious diseases, consequences of climate change, changes in demand). Angler saddle pigs come from regional breeding initiatives that, unlike large breeding companies, have limited financial resources, knowledge, and technology (Nürnberg et al., 2013).

The assessment of pork quality extends beyond its chemical composition and nutritional value, encompassing factors such as the health status of the animal, palatability, and technological indicators. These elements, influenced by the direction and intensity of post-slaughter biochemical autolytic processes, collectively contribute to the ultimate culinary, technological, and palatability characteristics of both raw meat and the finished product. The diversity in pork quality is primarily influenced by the intensity and scope of post-mortem proteolytic and glycolytic metabolism, which markedly impacts the listed meat properties.

The exploration of qualitative meat properties has captivated the attention of researchers for more than half a century. A multitude of biological traits have been identified as influential in determining the quality of both raw and processed meat. These traits encompass aspects related to microbiological conditions, physico-chemical properties, as well as culinary and technological value. The primary factors contributing to the degradation of pork quality include alterations in pig genotype, heightened intensification of breeding, maintenance, and nutrition methods, as well as stress-inducing conditions during pre-slaughter management and the slaughter process itself (including loading, transport, unloading, pre-slaughter storage duration

and conditions, stunning duration and conditions, and bleeding duration and position). (Koćwin-Podsiadła et al., 2006).

The quantity of intramuscular fat (IMF) and its specific fatty acid composition significantly influence the quality attributes of pork, particularly impacting sensory properties and raising concerns related to health. A commonly acknowledged consensus is that a higher intramuscular fat (IMF) content positively enhances the sensory quality traits of pork, while a lower amount of fat tends to result in less flavorful meat. Since pork is a significant source of dietary fat for humans, it has the potential to contribute to an imbalance in the fatty acid intake of today's consumers, which can be detrimental to human health.

Additionally, pork holds significance as a key component of the diet, and beyond its nutritional attributes, its sensory properties play a significant role in shaping consumer preferences. In response to consumer complaints, numerous studies have concentrated on enhancing the eating quality of pork by improving its organoleptic properties. These studies often target factors such as tenderness, juiciness, flavor, visual appearance, and overall acceptability, as evaluated by both consumer panels and trained sensory panels (Ngapo et al., 2004). Nevertheless, the sensory characteristics of pork can be subject to various influencing factors, including breed, age (or weight), gender, feeding practices, muscle type, ultimate pH, cooking methods, and fat content, including intramuscular fat content (IMF), commonly referred to as marbling. Within the contemporary meat production chain, genetics, diet, and specific meat quality attributes, such as water holding capacity (WHC), PH, color, and IMF content, are frequently identified as among the most crucial factors determining the sensory and eating quality of pork (Doran et al., 2006; Fortin et al., 2005). Some studies conducted earlier have indicated that the sensory properties of pork, including juiciness, tenderness, and overall acceptability, tend to be adversely impacted when the intramuscular fat content (IMF) falls below the range of 2–2.5%. As a result, there has been a proposal to establish a minimum threshold of 2.5% for intramuscular fat (IMF) content. This recommendation is aimed at ensuring a positive impact on the eating quality and sensory acceptability of pork, ultimately contributing to a favorable and enjoyable dining experience (Alfaia et al., 2019). If well-founded evidence of the positive characteristics of saddle pigs could be provided recommendations for appropriate feeding with roughage and predominantly regional feed components could be developed and indicators for appropriate pricing could be identified, this would

underline the suitability of saddle pigs for ecological husbandry conditions. This could further strengthen saddle pig husbandry in organic farming, but also overall ecological pig husbandry, which has so far only played a subordinate role nationwide and whose expansion will fuel the transformation towards sustainable agriculture with animal-friendly livestock husbandry. So, some pork features that can affect eating quality have been investigated in some previous studies.

2.1 Background

2.1.1 Eating quality:

The eating quality of meat remains the foremost determinant for consumers when considering repurchasing meat products. The specific attributes crucial to eating quality include:

Appearance: Visual appeal plays a pivotal role in the contemporary consumer's decision to purchase meat, as it frequently serves as the primary criterion for evaluating product quality. Therefore, consumers tend to assess meat based on factors such as water-holding capacity, color, fluid retention properties, and fat content. Flavor and taste: Taste is a complex interplay of numerous compounds generated during the heating of meat products. The evolution of flavor primarily hinges on constituents present in fresh meat, including fat composition, peptides, glycogen concentration, vitamin content—particularly thiamine and vitamin E and the thermal processing of the product. Elevated temperatures tend to enhance the development of flavor.

Tenderness: For an extended period, meat tenderness has been acknowledged as the paramount factor influencing consumer acceptance, with this attribute frequently cited as a common source of consumer dissatisfaction (Pearson, 1994).

Juiciness: Juiciness is linked to both the moisture content in the cooked product and the quantity of intramuscular fat (Andersen et al., 2005).

2.1.2 Water-holding Capacity:

Water Holding Capacity (WHC) denotes the quantity of water that the meat possesses the capability to retain throughout processes such as cutting, heating, grinding, and pressing. Water Holding Capacity (WHC) plays a pivotal role in not only influencing the visual acceptability of meat but also impacting the extent of water loss during transportation, storage, and cooking processes. The muscle tissue consists of

approximately 75% water during the rigor phase, and the incorporation of water into meat, along with post-cooking hydration, exhibits a close correlation with attributes such as taste, tenderness, color, and juiciness. In instances of suboptimal WHC, there is a tendency towards diminished cooking yields and the manifestation of 'dry' characteristics, indicative of a lack of juiciness. As such, these outcomes can serve as indirect measures for assessing WHC (Warner, 2014).

2.1.3 Color measurements:

The perceived color of meat is contingent upon the concentration and chemical state of the pigment myoglobin on its surface, coupled with the textural attributes of the meat and light scattering phenomena within its structural composition. The concentration of myoglobin on the meat surface, influencing attributes such as lightness and redness, exhibits variability not only among different muscles but also across species, with pork and chicken possessing lower muscle myoglobin content compared to beef and sheep meat. Additionally, the age of the animal contributes to these variations.

Meat from young animals, such as veal, tends to appear paler and less red due to lower muscle myoglobin content. The primary chemical states of myoglobin on the fresh meat surface include the reduced, purple deoxymyoglobin, the red oxymyoglobin characterized by a bound oxygen molecule, and the brown, reduced metmyoglobin. Rapid accumulation of metmyoglobin on the meat surface leads to a decline in consumer acceptability.

The predominance of deoxymyoglobin results in a dark, purple-red appearance of the meat, accompanied by reduced consumer acceptability. Light scattering within the muscle structure occurs when there is a swift pH decrease prerigor at an elevated muscle temperature, causing denaturation of muscle proteins and minimal gaps between myofibrils. Under these circumstances, characterized by a rapid pH decrease prerigor at elevated muscle temperatures, there is a notable augmentation in the scattering of incident light within the muscle structure. Consequently, the muscle surface exhibits a visual perception of being 'pale' or emitting 'less light' to detectors, whether human or machine. This phenomenon is particularly conspicuous in the condition recognized as PSE (Pale, Soft, Exudative) pork. Fluctuations in both pigment concentration and muscle structure give rise to discernible variations in the color of the meat surface, which are observable to the naked eye and quantifiable through machine-based measurements(Warner, 2014).

2.1.4 Intramuscular fat content (IMF):

The taste and crispness of meat are notably influenced by intramuscular fat, particularly its intercellular portion, giving rise to meat marbling characterized by the deposition of fat in the form of small veins(Suzuki et al., 2005; Wood et al., 2008) underscore intramuscular fat as a key parameter significantly impacting sensory characteristics and overall meat quality. Tasting tests recommend a level of 2.5% of intramuscular fat in M. longissimus lumborum thoracis (MLLT). Among pure breeds, Duroc stands out as the breed capable of attaining this specified intramuscular fat level (Sládek & Dračková, 2020).

Moreover, the presence of intramuscular fat in pork has been documented to exert a favorable influence on attributes such as juiciness, tenderness, and flavor, as highlighted by (Wood, 2008) has proposed that the intramuscular fat content in pork must surpass the threshold of 2% to elicit perceptible impacts on the sensory characteristics of the meat. The significance of fat and fatty acids extends beyond sensory aspects, encompassing their implications for human health. It is imperative to opt for production strategies that concurrently optimize both the quality of meat and its health attributes in meat production, as emphasized by Kouba et al., 2003.

Within developed nations, the composition of fatty acids, particularly the total quantity of saturated fatty acids (SFA), has been identified as a dietary risk factor (Pascual et al., 2007), correlating with various cancers and notably coronary heart disease. The composition of fat deposits is subject to modification by several factors, including species, breed, anatomical location, sex, and diet (Alonso et al., 2009).

Suzuki et al., (2005), note in their study that Duroc demonstrates the highest values of intramuscular fat content compared to other pig breeds. Additionally, Lo et al., (1992) report in their studies a higher intramuscular fat content ranging from 2.4% to 4.5% in the Duroc breed when compared to Large White and Landrace breeds. Hybrids incorporating Duroc also exhibit elevated intramuscular fat content compared to hybrids from other breeds(Sládek & Dračková, 2020).

The meat from Angler and German saddle pigs is characterized by a high content of intramuscular fat (IMF). At the same time, however, saddle pigs achieve relatively low muscle meat percentages (Well et al., 2011; Nürnberg et al. 2013). When paying according to the usual trade classification, this leads to very low revenues. However, profitability is an important prerequisite for the preservation of the breed. Breeders and

fatteners of saddle pigs need other pricing parameters than the lean meat portion for the successful marketing of products from saddle pigs. So far there have been no criteria that can be measured in practice (on the carcass) that can prove the special meat quality.

2.1.5 Protein Measurement:

Protein derived from animal sources exhibits distinct characteristics in comparison to that sourced from vegetables. Primarily, animal products surpass vegetable counterparts in their richness of the eight essential amino acids, crucial components of proteins that the body cannot synthesize and must acquire from dietary sources. Animal products contribute substantially, providing nearly three-fourths of the essential amino acids and accounting for approximately 67 percent of the total protein in the food supply. This discrepancy underscores the heightened concentration of these vital nutrients in animal-derived proteins.

It is noteworthy that both animal and vegetable proteins typically undergo some form of processing, commonly cooking, before consumption. The impact of this processing on protein bioavailability becomes pivotal, particularly in estimating the effective protein content within the food supply. Adequate cooking plays a role in enhancing digestion and utilization by partially breaking down the protein structure. Nevertheless, excessive or prolonged heating can lead to the formation of new chemical bonds, thereby diminishing protein digestibility. An illustrative example is the diminished physiological availability of lysine, tryptophan, and other amino acids in toasted cereal products, where high heat induces the formation of resistant bonds between lysine and carbohydrates (Love, 1982).

Furthermore, severe heating of animal proteins has been demonstrated to disrupt cystine and result in reduced digestibility and availability of amino acids (Cheftel, 1977). Consequently, understanding the effects of processing on protein bioavailability is crucial for accurate assessments of the protein content available for utilization by the body (National Research Council (U.S.). Committee on Technological Options to Improve the Nutritional Attributes of Animal Products., 1988).

In addition, the imperative functions encompassing tissue repair, lean tissue growth (musculature), reproductive processes, and lactation necessitate meticulous consideration of the constituent amino acids rather than merely the gross protein content in a given feedstock. For optimal physiological performance, it is crucial to

ensure a balanced supply of these (e amino acids tailored to the specific functional requirements. Lysine emerges as the frequently limiting amino acid in porcine diets, and an insufficient quantity thereof hampers the utilization of surplus amino acids, leading to their wastage. The surplus protein is excreted by swine, serving as a significant nutrient (nitrogen) replenishment for the soil but concurrently posing a potential risk of environmental pollution(Edwards, 2002).

2.1.6 PH value:

Pork has been categorized into four groups, namely PSE (pale, soft, exudative), RSE (reddish-pink, soft, and exudative), RFN (reddish-pink, firm, and non-exudative), and DFD (dark, firm, and dry), based on their classification criteria as outlined by Lee et al., 2000 PSE and DFD meats are distinguished based on criteria such as pH value, color (CIE L* value), and drip loss. However, consumers tend to exhibit a preference against these types of meats, as indicated by studies by Adzitey & Nurul, 2011 and Van de Perre et al., 2010. Additionally, the quality of meat is influenced by various factors such as the genetic traits of the pig, conditions before slaughter, the method of slaughter, and handling both pre- and post-slaughter, as highlighted in research by Xu et al., 2012. Consequently, meat quality is generally defined as the collective attributes of meat, and these characteristics are modulated by the muscular pH, as discussed by Pearce et al., 2011. The live pig's muscle typically possesses a neutral pH value ranging from 7.0 to 7.2. During the transition from muscle to meat, the absence of oxygen supply leads to anoxia, resulting in a decrease in pH. This process causes the accumulation of organic acids, such as lactic acid, or inorganic acids in the muscle, as outlined by Pearce et al., 2011. The buildup of acidic substances leads to acidification and a subsequent decrease in pH. The post-mortem pH of the muscle and the rate of pH decline significantly impact water holding capacity, which, in turn, determines both drip loss in raw pork and cooking loss during the cooking process (Pearce et al., 2011). Measurement of the post-mortem pH is commonly conducted within 1-hour post-slaughter (initial pH or pH 45 minutes) or within 24 hours (ultimate pH or pH 24 hours). According to PIC, 2003 recommendations, the optimal ranges for initial and ultimate pH are 6.3 to 6.7 and 5.7 to 6.1, respectively. If the initial pH is 5.8 or less, there is a high likelihood that the ultimate pH of the meat will remain below 5.5, potentially leading to the conversion of pork into the PSE category due to excessively low pH and rapid pH decrease.

Contrastingly, meat with an ultimate pH above 6.1 is categorized as DFD due to the absence of a decrease in pH to a normal level. PSE meat is characterized by pH45min and ultimate pH24h values of 6.0 or less and 5.3, respectively, whereas DFD meat has values of 6.4 and 6.0 or more, respectively, as defined by Warriss, 2000. In comparison, normal meat maintains pH45min and ultimate pH24h values of 6.4 and 5.5, respectively, according to findings by Adzitey & Nurul, 2011. Furthermore, the rate at which pH decreases post-mortem is a crucial factor influencing meat color and water-holding capacity (Tomović et al., 2014; Wan Kim et al., 2016).

2.1.7 Feeding strategy and diet composition:

The feeding regimen and dietary composition can exert a significant influence on the palatability of meat. Constrictive feeding practices have been demonstrated to yield suboptimal eating quality, particularly in terms of tenderness, as compared to ad libitum feeding in both porcine (Danielsen et al., 1999) and bovine species (Therkildsen et al., 2002). Recent findings indicate that an approach involving compensatory growth, characterized by a sequential transition from restrictive feeding to ad libitum feeding, may enhance tenderness in meat derived from both porcine (Allingham et al., 1998 and Therkildsen & Karlsson, 2002) sources, surpassing the tenderness observed in meat from animals subjected solely to ad libitum feeding.

Moreover, feeding strategies grounded in pasture-based regimens may result in diminished eating quality, manifested through reduced tenderness and unfavorable flavor assessments in comparison to grain-fed counterparts. Nevertheless, this issue can be mitigated through the introduction of a finishing feeding phase involving concentrate (Vestergaard et al., 2000).

While compelling data are currently lacking to affirm a direct positive influence of feed composition on meat flavor, literature presents numerous instances where certain feed components contribute to undesirable off-flavors. For instance, rape seed (Brassica napus) containing elevated levels of bitter compounds and fish meal have been identified as sources of off-flavors. As a result, it is advisable to omit such feed components from diets, particularly when managing monogastric animals (Andersen et al., 2005).

Furthermore, the breed should be characterized by a special ability to use roughage. So far, there has been little scientific evidence for these properties and practical recommendations for action. Concerning feeding, it is known that saddle pigs can be

fed to a not-inconsiderable extent with the farm's feed components, but farms and the advice service lack manageable feeding recommendations. The consultation shows that the use of roughage on the farms is often not targeted. For the most part, the roughage is presented as manipulative material only, although there are obvious benefits of feeding roughage. Opportunities for saving concentrated feed in the form of cereals and grain legumes thus remain unused. Feeding also has an impact on meat quality. If well-founded evidence of the positive characteristics of saddle pigs could be provided recommendations for appropriate feeding with roughage and predominantly regional feed components could be developed and indicators for appropriate pricing could be identified, this would underline the suitability of saddle pigs for ecological husbandry conditions. This could further strengthen saddle pig husbandry in organic farming, but also overall ecological pig husbandry, which has so far only played a subordinate role nationwide and whose expansion will fuel the transformation towards sustainable agriculture with animal-friendly livestock husbandry.

This project is part of a big project and the Involved persons/institutions that cooperate are Farmers, the University of Kassel, and HAW-Hamburg.
Contents: This work package starts with a survey of stakeholders to get an impression of the status quo in the pricing and marketing of saddle pig meat in advance. The core of this work package is to record the meat quality of the animals in the fattening experiment. Some of the analyses take place directly in the slaughterhouse of the performance testing facility in Ruhlsdorf. Subsequently, samples for more in-depth evaluations (including fatty acid samples) are analyzed at the HAW in Hamburg, where a sensory evaluation is also carried out by appropriately trained panels. After completion of the data evaluation (plan for mid-2024), the results will be discussed with all those involved in the work package and recommendations will be made for adjusted pricing for the marketing of meat from angler saddle pigs.

3. Aim of study

This research aims to compare the quality attributes of saddle pig meat from organic and conventional sources, specifically focusing on color, intramuscular fat content, protein content, and hydroxyproline levels. By conducting this study, the aim is to

evaluate and potentially highlight any significant differences between the two types of meat. In addition, the identification of evidence-based parameters that are to be collected under practical conditions and that document the unique quality of the meat and thus make adjusted pricing possible.

Various positive characteristics are attributed to saddle pigs. The animals are considered to be robust with good mothering qualities. Especially in organic animal husbandry, but also increasingly in other husbandry methods, husbandry is determined or characterized by free farrowing. Here it is of particular importance that in the first five days of life, particularly low crushing losses occur in piglets. Furthermore, the robustness against the background of highly variable extensive husbandry conditions represents an important property. Verifiable statements on the aforementioned properties have not yet been made for the saddle pigs. If well-founded evidence of the positive characteristics of saddle pigs could be provided recommendations for appropriate feeding with roughage and predominantly regional feed components could be developed and indicators for appropriate pricing could be identified, this would underline the suitability of saddle pigs for ecological husbandry conditions. This could further strengthen saddle pig husbandry in organic farming, but also overall ecological pig husbandry, which has so far only played a subordinate role nationwide and whose expansion will fuel the transformation towards sustainable agriculture with animal-friendly livestock husbandry.

4. The main research questions for this thesis include

How does the color of saddle pig meat from organic and conventional sources differ?

Is there a significant difference in the intramuscular fat content between organic and conventional saddle pig meat?

Do organic and conventional saddle pig meat differ in terms of protein content?

What are the levels of hydroxyproline in organic and conventional saddle pig meat, and is there a significant variation between the two?

By addressing these research questions, we will be able to compare the key quality attributes of organic and conventional saddle pig meat and draw conclusions regarding their differences, if any, in terms of color, intramuscular fat content, protein content, and hydroxyproline levels.

5. Material and Methods

From a population of 50 saddle pigs, 27 have been selected using stratified random sampling. Pigs were transported to a slaughterhouse, rested for 12 hours, then were killed, and then refrigerated overnight when their mean live weight reached 110 ± 10kg. They were killed without the use of electricity and kept in cold storage for 24 hours at 0 °C. 24 hours after the death, the cold carcasses were rated. Longissimus muscle from the left side of the carcass and fixed place between the fifth and thirteenth rib samples, as well as backfat (BF), were taken out and submitted to the lab. Each carcass was divided into pieces of backfat measuring 5 cm by 5 cm and weighing around 70 to 150 g (5 g) and 500 g (10 g), respectively, from the subcutaneous fat surface to the muscle layer (Chernukha et al., 2023).

Sample size: There will be a total of 27 saddle pigs in the sample. This sample size is practical for a master's thesis project given the time and resource constraints and is sufficient for obtaining statistically meaningful results.

Sampling frequency: For the master's thesis, the sampling plan will be used just once. This frequency guarantees that the data gathered is adequate for analysis and conclusions and is suitable for a master's thesis topic.

5.1 Plan of Experiment:

The quality of the meat, particularly its color, texture, hydroxyproline concentration, and protein/fat content, may be impacted by the saddle pigs' feeding practices, according to research. In terms of color, texture, and protein content, saddle pigs fed a higher protein diet will produce meat of greater quality. Conversely, saddle pigs fed a higher-fat diet will produce meat of higher quality in terms of fat content and hydroxyproline content.

Feeding period: Feed the pigs for a period of 120 days, with daily monitoring of the feeding regime and health status of the pigs.

Slaughter and meat sampling: Used normal techniques to kill the pigs, then take meat samples from their shoulder and belly. PH, water holding capacity, and temperature as soon as possible after the animal has been killed should be measured (Zhu et al., 2023).

Analytical statistics Analyze the data and test the hypothesis using the relevant statistical tests (ANOVA, analysis of variance). The statistical applications are Minitab

and Excell. Ethics-related factors Animal care laws and ethical standards should be followed during the experiment. The pigs should be cared for and fed properly, and the killing should adhere to established procedures to reduce animal suffering.

5.2 Color measurement:

Colorimeters operate on reflected light, transmission via a cuvette, or maintenance of both measuring techniques. Some colorimeters can see the spectral response that results in the visible range. The measurement data are shown on the display, and utilizing extra software and a communication port, they may also be sent to a computer for additional analysis (Baycheva & Байчева, 2016).

Like the big spectrophotometers, the RM200QC Colorimeter enables us to compare the color of the standard and sample. To compare samples that often appear on-site with the standards saved and to preserve the measurement values acquired at the end of the day in report form or as a CSV file on the PC, it maintains 20 standards and 350 samples. The RM200QC is a portable color measurement device that can be used to measure the color of meat samples, including saddle pig meat. The device measures color using a spectrophotometer and provides L*, a*, b*, C*, h°, and ΔE* values.

Here are the steps involved in measuring the color of saddle pig meat using the RM200QC:

Sample preparation: Firstly, take a representative sample of the saddle pig meat and put a grid on the meat and then each segment of the sample should be measured by the Coulorpin and colorimeter. Additionally, we should also prepare six standard samples. It means that the color of three conventional and three organic samples to compare with our samples should be measured.

Calibration: Turn on the RM200QC and follow the manufacturer's instructions to calibrate the device using a white or gray standard.

Measurement: Place the meat sample in the measurement area of the device and take a reading. The device will provide L*, a*, b*, C*, h°, ΔE*, and values for the sample.

Interpretation: Compare the color values for the sample with conventional and organic samples to evaluate the quality of the meat. After this step, our original samples, and standards (three conventional and three organic samples) should be homogenized for measuring their colors with a Konica CM-5 spectrophotometer and for measuring other chemical factors that will be explained.

Now, to measure the color of homogenized pig meat using a Konica CM-5 spectrophotometer, we followed these steps:

The homogenized pig meat sample which has been illustrated in Fig. 1, should be adequately prepared and ready for measurement while preparing the samples. To achieve homogeneity, the sample should be completely homogenized. Then, Calibrate the Konica CM-5 spectrophotometer using the proper calibration standards before beginning the measurement.

The next step is that for measuring color, the spectrophotometer should be calibrated to suitable parameters. Usually, this entails picking the proper color space (such CIE Lab* or CIE LCh*) and wavelength range.

Baseline measurement: Record the reference or blank measurement by using an empty container or cuvette as the baseline measurement source. This measurement takes into consideration any contaminants or background interference.

To measure the sample, swap out the empty container for the one holding the homogenized pig flesh sample. Make sure the sample fills the cuvette's measuring area and is distributed evenly. Record the color measurement after inserting the cuvette into the spectrophotometer. Finally, data analysis is based on the chosen color space, the Konica CM-5 spectrophotometer reports color values when the measurement is complete. These parameters might be brightness, chroma, and hue for CIE LCh* color space or L*, a, and b values for CIE Lab* color space. Determine the color features of the homogenized pig flesh sample by analyzing these values (Cozzolino et al., 2003).

Fig.1 The pig meat sample

5.3 Intramuscular Fat Content (IMF) and total protein content:

Meat's total fat and protein composition should be measured to assess the meat's nutritional worth and quality. Following are the procedures for determining the amount of total fat and protein in saddle pig meat: preparing a sample removes all visible fat and connective tissue from a representative sample of the saddle pig flesh. Make a fine powder out of the meat sample using a meat grinder or blender. We can measure the value of total fat in the pig sample using the Soxhlet extraction method (Fig.2) or a solvent extraction method. Although the solvent extraction method requires adding a solvent to the sample and shaking it to extract the fat, the Soxhlet extraction method frequently boils the sample in a solvent. To measure the total fat content as a percentage of the sample, the extracted fat can be dried and weighed after being weighed to appraise its mass (Ellefson, 2017).

Fig.2 Soxhlet extraction apparatus Rotary evaporator

Measuring the protein content of the pig meat samples: Use either the Kjeldahl or the Dumas methods to ascertain the protein level. By converting the sample's nitrogen to ammonium sulfate, which can be measured using titration or colorimetric techniques, the Kjeldahl method entails digesting the sample in sulfuric acid. To determine the sample's nitrogen concentration using gas chromatography, the Dumas technique entails burning the sample in a furnace. According to ISO 5983-2:2005, the nitrogen concentration plus a conversion factor can be used to compute the protein content as a percentage of the sample.

Interpretation: Compare the total fat and protein content of the saddle pig meat with reference values or industry standards to evaluate its quality and nutritional value. When carrying out these measures, it is decisive to adhere to suitable safety cautions and industry-standard laboratory practices. In addition, elements including sample preparation, device calibration, and analytical methods may have an impact on the accuracy and precision of the measurements.

5.3.1 Procedure

For the measurement of IMF:

1. Rinse all glassware with petroleum spirit, drain, dry in an oven at 102ºC for 30 min., and cool in a desiccator.
2. Place a piece of cotton wool in the bottom of a 100 mL beaker. Put a plug of cotton wool in the bottom of an extraction thimble and stand the thimble in the beaker.

3. Accurately weigh 5 g of sample into the thimble. Add 1 - 1.5 g of sand and mix the sand and sample with a glass rod. Wipe the glass rod with a piece of cotton wool and place cotton wool on the top of the thimble.
4. Take the piece of cotton wool from the bottom of the beaker and place it in the 3 tops of the thimble.
5. Insert the thimble in a Soxhlet liquid/solid extractor
6. Accurately weigh a clean, dry 150 mL round bottom flash and put about 90 mL of petroleum spirit into the flask.
7. Assemble the extraction unit over either an electric heating mantle or a water bath.
8. Heat the solvent in the flask until it boils. Adjust the heat source so that solvent drips from the condenser into the sample chamber at the rate of about 6 drops per second.
9. Continue the extraction for 3 hours.
10. Remove the extraction unit from the heat source and detach the extractor and condenser. Replace the flask on the heat source and evaporate off the solvent. (The solvent may be distilled and recovered).
11. Place the flask in an oven at 102ºC and dry the contents until a constant weight is reached.
12. Cool the flask in a desiccator and weigh the flask and its contents.
Weight of empty flask (g) = W1
Weight of flask and extracted fat (g) = W2
Weight of sample = S
%Crude fat = (W2 – W1) x 100/S

First, let's work on improving the clarity, grammar, and flow of the passage:
"At first, we prepared our samples and separated them into three parts: muscle, fat, and bone. The muscle part was crucial as we needed to measure its fat content. This work was carried out in Professor Riehn's food lab. Once separated, the samples were placed in a freezer.
To homogenize the muscle samples without raising their temperature, we cut each sample into small pieces before freezing them. We opted to use a thermomixer from the well-equipped food technology lab at HAW-Hamburg University. It's worth noting that high temperatures can destroy protein content, so we ensured the samples remained below or at 0 degrees Celsius during homogenization.

With the homogenization step complete, we proceeded to measure the fat content. We found a successful method that was both comfortable and comprehensive, and suitable for raw meat analysis. However, it is essential to mention that this method can be time-consuming, taking around 4 to 16 hours, depending on the drip rate for successful extraction. If the samples had more than 10% water content, we preferred drying them to a constant weight at 95 to 100 degrees Celsius under or equal to a pressure of 100 mmHg for approximately three hours.

To start the extraction, we weighed approximately 5 to 10 grams of the sample and placed it onto filter paper. The sample was then put into a thimble and sealed with a piece of fat-free cotton wool. Using a suitable solvent is crucial in this process, as some solvents can be dangerous when combined with heat. Petroleum ether or hexane can be used safely. Next, we assembled the extraction apparatus by placing the sample-containing thimble inside the machine chamber. The solvent was poured onto the thimble, and a condenser was placed on top. The extraction apparatus was then activated, and we waited for about four to five hours for the fat to be extracted, depending on the sample type.

After the extraction, we needed to evaporate the solvent. To do this, we turned on a rotation apparatus to convert the solvent back to liquid form. The fat content was collected in the boiling flask. The flask was then placed into an oven set at 103 degrees Celsius for about 30 minutes to remove any residual water. Once the flask's temperature reached equilibrium, we could weigh it with the fat content using the same scale from the first step. This was the final step of our work, and with the measured fat content, we were able to formulate our results accurately.

For the measurement of protein:

$$W_N = \frac{(V\text{-}V_0)*f*1{,}4008*N}{E}$$

W_N: Represents the weight or mass of nitrogen, which is used as a basis to calculate the protein content.

V: the final volume of a titrant used in a titration process.

V0: The initial volume of the titrant before the process begins.

f: A factor that represents the correction factor or a conversion factor specific to the method or substance being analyzed.
1.4008: This constant could be specific to the method used, which is related to the molecular weight of nitrogen or a conversion factor in the context of the analysis.
N: This represents the normality of the titrant solution used in the analysis.
E: Could denote the equivalent weight of the substance being analyzed, a factor necessary to convert volumes and normality into mass.
To summarize, the process involves titrating a sample to measure the amount of nitrogen, and this measured nitrogen content is then used to calculate the protein content using the factors and constants provided in the formula. The value of WN calculated from this formula is then used in the first formula to find the protein content (W prot) using the relation:

$$W_{Prot} = w_N * F$$

Where F is the conversion factor specific to the type of meat or the protein under analysis.

6. Statistical analysis

Statistical analyses were conducted utilizing Excel and Minitab software (version 20.1.1.0), with significance determined at $p \leq 0.05$.

7. Result and Discussions

The independent variable is indeed the effect of feeding but also genetics. However, because the project is part of a joint project and we did not focus on the genetics of pigs, we considered just feeding as the independent variable. All samples belong to one trial (one group of pigs that are kept and fattened under the same conditions). SCHL marks the slaughter number and PVC as the individual number of each pig.

7.1 Intramuscular fat content (IMF):

Intramuscular fat content is one of the important factors to analyze for meat quality. So, we have 30 factors (different samples) and two repetitions for each sample. We use one-way ANOVA to compare the means of multiple groups. The null hypothesis

was that all means are equal, while the alternative hypothesis was that not all means are equal. The significance level was set at $\alpha \leq 0.05$.

The ANOVA results indicate a significant difference among the groups (Factor) with an F-value of 64.17 and a p-value of 0.000 as shown in Table 1, rejecting the null hypothesis. This suggests that at least one group's mean is significantly different from the others. The model summary shows that the variation in the dependent variable can be explained by the factor to a large extent, with an R-squared value of 98.41%. The adjusted R-squared and predicted R-squared values are also high, indicating a good fit for the model.

The Tukey pairwise comparisons further illustrate the groupings of means that are significantly different from each other.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	29	133.742	4.61180	64.17	0.000
Error	30	2.156	0.07187		
Total	59	135.898			

Table. 1. Analysis of Variance

The ANOVA results indicate significant differences among the groups. Group A (Bio) has the highest mean and is significantly different from all other groups. Group N (PERSA Sch.EOEKA HS2) has the lowest mean and is importantly different from all other groups.

The highest mean (Bio) and the lowest mean (PERSA Sch.EOEKA HS2) show a clear gradient of differences among the groups, with each group significantly differing from multiple other groups.

Group A: Bio (6.175) is significantly different from all other groups.

Group B: PVC 048. Schl 26 (5.5000) is significantly different from Group A (Bio) but not from any other group.

Group C: PVC 006. Schl 27 (4.9650), PVC 021. Schl 22 (3.665), PVC 058. Schl 27 (3.5750), and PVC 005. Schl 22 (3.425) are significantly different from Groups A and B but not from each other.

Group D: PVC 050. Schl 17 (2.975), PVC 020. Schl 25 (2.925), PVC 056. Schl 21 (2.705), and PVC 022. Schl 23 (2.6000) are significantly different from Groups A, B, and C but not from each other.

Group E: PVC 019. Schl 26 (2.3900), PVC 061. Schl 24 (2.205), PVC 047. Schl 24 (2.155), PVC 057. Schl 26 (2.060), and PVC 043. Schl 25 (2.0450) are significantly different from Groups A, B, C, and D but not from each other.

Group F: PVC 049. Schl 23 (1.7300) is significantly different from Groups A to E but not from Group M.

Group G: PVC 045. Schl 21 (1.535) and PVC 059. Schl 25 (1.5300) are significantly different from Groups A to F but not from each other.

Group H: PVC 064. Schl 20 (1.490) and PVC 055. Schl 23 (1.415) are significantly different from Groups A to G but not from each other.

Group I: PVC 063. Schl 24 (1.1500) is significantly different from Groups A to H but not from Group N. Group J: PVC 066. Schl 20 (0.9650) is significantly different from Groups A to I but not from Group N. Group K: PVC 046. Schl 24 (0.8700) is significantly different from Groups A to J but not from Group N. Group L: PVC 014. Schl 25 (0.6950) and Kottelete Schwein (0.540) are significantly different from Groups A to K but not from each other. Group M: PVC 062. Schl 22 (0.440) and PVC 065. Schl 18 (0.3550) are significantly different from Groups A to L but not from each other. Group N: PERSA Sch. EOEKA HS2 (0.15500) is significantly different from Groups A to M (Fig.3).

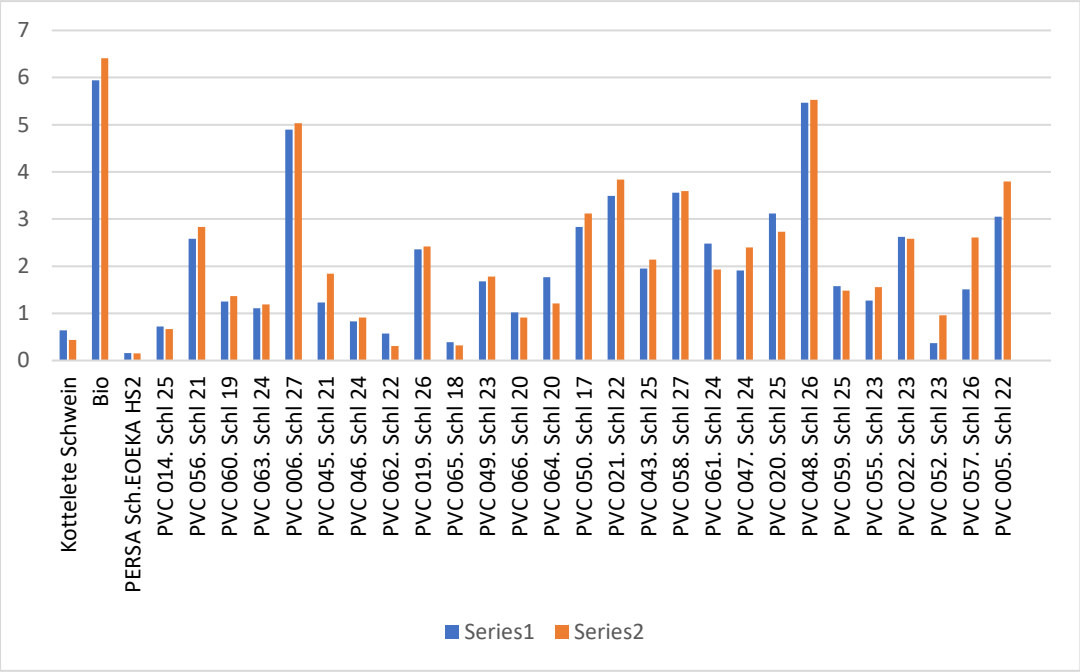

Fig.3. The percentage comparison of Intramuscular fat content

Intramuscular fat content (IMF) could be a basic determinant of meat quality, essentially impacting its flavor, deliciousness, and delicacy. High IMF levels are by

and large related to moved-forward agreeability, whereas lower levels may demonstrate leaner meat, which can be less delicate and flavorful but is frequently favored for its well-being benefits (Wood et al., 2004).

Group N (PERSA Sch.EOEKA HS2) had the lowest mean IMF (0.15500), indicating a leaner meat type that might be less tender but could appeal to health-conscious consumers. In our study, Group A (Bio) had the highest mean IMF (6.175), which is significantly different from all other groups. This finding is consistent with the findings of Thompson (2004), who emphasized that meat with higher IMF content generally receives better ratings in consumer taste tests (Thompson, 2002), also the idea that group A (Bio) group represents meat with greater eating quality is supported by the much higher IMF content, which is in line with the findings of Moeller et al., 2010.

7.2 Color measurement (RM200QC):

We use one-way ANOVA (Analysis of Variance) to compare the means of multiple groups. The null hypothesis was that all means are equal, while the alternative hypothesis was that not all means are equal. The significance level was set at $\alpha \leq 0.05$.

The Tukey Pairwise Comparisons method was applied to evaluate the mean differences among 32 different groups, with a 95% confidence interval. This analysis helps to determine which groups have significantly different means. Each factor is categorized into different groups, labeled A, B, and C, based on the similarity of their means. Factors that share the same letter are not significantly different, while those that do not share a letter are significantly different.

The factors are grouped based on their means as follows:

Group A: Factors in this group have the highest means and are not significantly different from each other.

Group B: Factors in this group have intermediate means and overlap with Group A.

Group C: Factors in this group have the lowest means and do not overlap with the highest means in Group A. The Tukey post-hoc test was conducted to compare the means of different groups to determine which pairs are significantly different from one another. Below is a detailed explanation of these comparisons, organized by significant groupings.

Groupings Based on Tukey Pairwise Comparisons:

Group A: PVC 065. Schl 18 (42.85), PVC 060. Schl 19 (42.30), and PVC 064. Schl 20 (42.20) were the highest means. These groups did not show significant differences among themselves but were significantly different from groups with lower means.

Group A and B: PVC 063. Schl 24 (41.50), PVC 049. Schl 23 (41.37), PVC 050. Schl 17 (41.19), PVC 059. Schl 25 (40.97), PVC 046. Schl 24 (40.76), and PVC 043. Schl 25 (40.58). These groups overlapped with the top groups (A) and the next intermediate groups (B), indicating that their means were close enough to not be significantly different from both the highest and the intermediate means.

Group A, B, and C: PVC 066. Schl 20 (39.77), PVC 020. Schl 25 (39.43), PVC 047. Schl 24 (39.05), PVC 052. Schl 23 (38.88), PVC 062. Schl 22 (38.81), PVC 048. Schl 26 (38.78), PVC 045. Schl 21 (38.66), PVC 058. Schl 27 (38.46), PERSA H2.1 (38.17), Kottelete Schwein2 (38.10), PVC 055. Schl 23 (37.73), Kottelete Schwein1 (37.64), and PERSA H2.2 (37.62). These groups had means that were not significantly different from the highest means (A) but also were not significantly different from the lowest means (C).

Group B and C: PVC 022. Schl 23 (37.09), PVC 014. Schl 25 (37.01), PVC 057. Schl 26 (36.69), PVC 021. Schl 22 (36.12), PVC 056. Schl 21 (36.09), PVC 019. Schl 26 (35.95), PVC 006. Schl 27 (35.58), and PVC 005. Schl 22 (35.14). These groups had intermediate means that were not significantly different from the lower intermediate means (B) and the lowest means (C).

Group C: Bio1 (34.28) and Bio2 (33.48) were the lowest means. These groups were significantly different from all higher mean groups (A) and many of the intermediate mean groups (B and some C).

Analysis of Significance:

The results of the Tukey test indicate that there are significant differences between certain groups. Groups that share the same letter in the Tukey grouping (e.g., A, B, C) are not significantly different from each other, while those that do not share a letter are significantly different (Table 2).

High Mean Groups (A): PVC 065. Schl 18, PVC 060. Schl 19, and PVC 064. Schl 20 were significantly different from the Bio1 and Bio2 groups but not significantly different from each other.

Intermediate Mean Groups (A, B, C): PVC 063. Schl 24 through PERSA H2.2 had means that were not significantly different from each other but spanned the range from high to intermediate, showing some overlap with both higher and lower groups.

Low Mean Groups (C): Bio1 and Bio2 were significantly different from most other groups, indicating that they had the lowest performance in comparison.

For better color measurements based on Delta E values, the groups with the lowest means are considered the best. These are:

Bio2: Mean = 33.48

Bio1: Mean = 34.28

These groups demonstrated the best performance in color measurement, making them the preferred choices. The groups with slightly higher but still low ΔE* values also performed well and can be considered good, while the groups with the highest ΔE* values showed the least desirable color measurements.

Factor	N	Mean	Grouping		
PVC 065. Schl 18	10	42.85	A		
PVC 060. Schl 19	10	42.30	A	B	
PVC 064. Schl 20	10	42.20	A	B	
PVC 063. Schl 24	10	41.50	A	B	C
PVC 049. Schl 23	10	41.37	A	B	C
PVC 050. Schl 17	10	41.19	A	B	C
PVC 059. Schl 25	10	40.97	A	B	C
PVC 046. Schl 24	10	40.76	A	B	C
PVC 043. Schl 25	10	40.58	A	B	C
PVC 066. Schl 20	10	39.77	A	B	C
PVC 020. Schl 25	10	39.43	A	B	C
PVC 047. Schl 24	10	39.05	A	B	C
PVC 052. Schl 23	10	38.88	A	B	C
PVC 062. Schl 22	10	38.81	A	B	C
PVC 048. Schl 26	10	38.78	A	B	C
PVC 045. Schl 21	10	38.66	A	B	C
PVC 058. Schl 27	10	38.46	A	B	C
PERSA H2.1	10	38.170	A	B	C
Kottelete Schwein2	10	38.100	A	B	C
PVC 055. Schl 23	10	37.73	A	B	C
Kottelete Schwein1	10	37.640	A	B	C
PERSA H2.2	10	37.620	A	B	C
PVC 022. Schl 23	10	37.09	A	B	C
PVC 014. Schl 25	10	37.01	A	B	C
PVC 057. Schl 26	10	36.69	A	B	C
PVC 021. Schl 22	10	36.12	A	B	C
PVC 056. Schl 21	10	36.09	A	B	C
PVC 019. Schl 26	10	35.95	A	B	C
PVC 006. Schl 27	10	35.58	A	B	C
PVC 005. Schl 22	10	35.14	A	B	C
Bio1	10	34.28		B	C
Bio2	10	33.480			C

Table 2. Grouping Information Using the Tukey Method and 95% Confidence

Means that do not share a letter are significantly different.

Moreover, another device used to measure the color of meats after homogenization was the spectrophotometer CM-5 Konica. The results are as follows and Fig.4:

We use one-way ANOVA (Analysis of Variance) to compare the means of multiple groups. The null hypothesis was that all means are equal, while the alternative hypothesis was that not all means are equal. The significance level was set at $\alpha \leq 0.05$. The mean values for each group and the grouping from Tukey's HSD (Honestly Significant Difference) test are provided. Means that do not share a letter are significantly different from each other.

PERSA Sch. EOEKA HS2_1 has the highest mean (33.150) and forms its own group 'A'.

PVC 059. Schl 25 has the lowest mean (30.100) and forms its own group 'G'.

Group A (PERSA Sch. EOEKA HS2_1):

Mean: 33.150. This group has the highest mean and is significantly different from all other groups.

Group B (PVC 066. Schl 20, PVC 006. Schl 27, PVC 064. Schl 20, Kottelete Schwein_1, Kottelete Schwein):

Mean Range: 31.400 to 31.650. These groups are not significantly different from each other but are significantly different from Group A.

Groups B to G: These groups have means that range from 30.100 to 31.200. They form overlapping groupings (B, C, D, E, F, G), indicating some similarities and some differences among their means. For example, PVC 056. Schl 21 and PVC 048. Schl 26 share group letters B, C, D, E, F, indicating they are not significantly different from each other, but they are different from groups beyond this range.

Group G (PVC 059. Schl 25):

Mean: 30.100. This group has the lowest mean and is significantly different from all other groups except for the groups closest to the means, such as PVC 063. Schl 24 and PVC 005. Schl 22 (which form the subgroup F G).

In general, PERSA Sch. EOEKA HS2_1 vs. All Other Groups. This group is significantly higher than all other groups.

PVC 066. Schl 20, PVC 006. Schl 27, PVC 064. Schl 20:

These groups have relatively high means and are not significantly different from each other but are different from the groups with lower means.

Groups with Overlapping Letters:

Groups with overlapping letters (e.g., B C D E F G) indicate no significant differences among them, but they are different from groups outside this range.

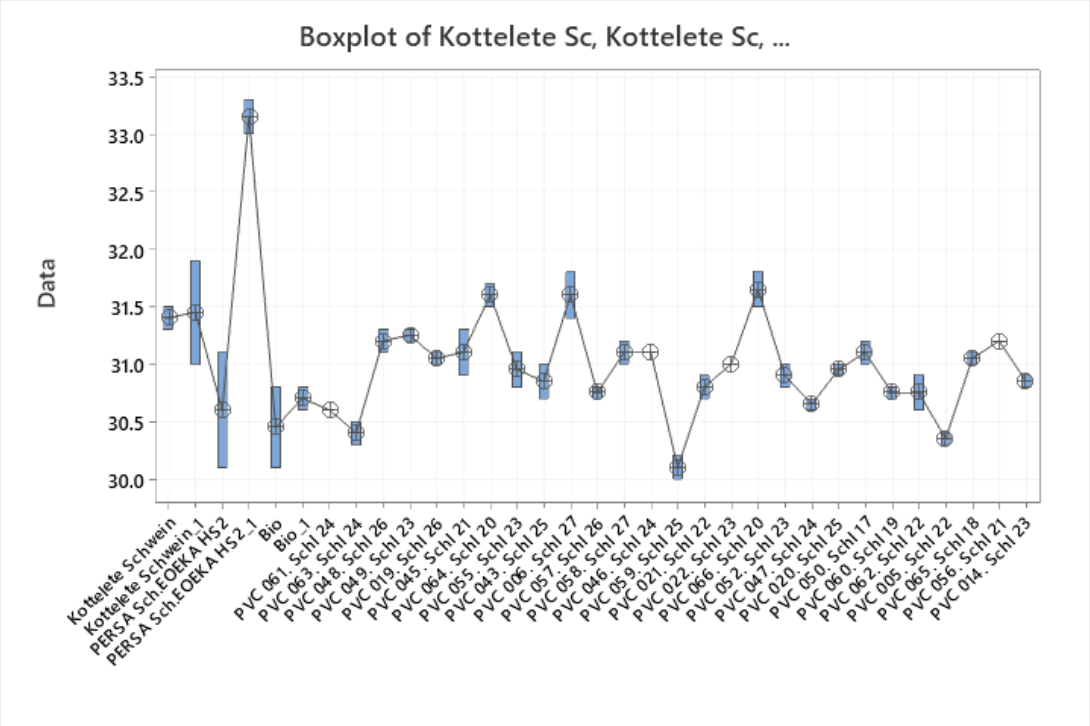

Fig.4. Color measurement of samples (Spectrophotometer CM-5 Konica)

The substantial variations in meat color found in this investigation are consistent with other studies that emphasize the significance of color as a meat quality indicator. Mancini and Hunt (2005) have reported that many variables, including muscle type, myoglobin level, and postmortem management, can significantly affect the color measures of meat. The many categories found in this study are indicative of this variety (Mancini & Hunt, 2005). Moreover, Brighter hues often indicate fresher and higher-quality meat, according to Faustman & Cassens (1990), who stressed the importance of meat color stability for customer acceptability. When compared to the lower values in Group C (Bio1 and Bio2), the higher mean color values in Group A (PVC 065, Schl 18, PVC 060, Schl 19, and PVC 064, Schl 20) in the first measurement of the samples indicate greater perceived quality.

Liu et al. (2004) discovered that meat color has a substantial impact on customer preferences, with brilliant red and fewer discolored meats being preferred. This validates the study's findings, which suggest that higher mean color value groupings are probably seen as greater quality (Liu et al., 2003).

7.3 Protein content:

We use one-way ANOVA (Analysis of Variance) to compare the means of multiple groups. The null hypothesis was that all means are equal, while the alternative hypothesis was that not all means are equal. The significance level was set at $\alpha \leq 0.05$. However, as the result of the analysis of variance illustrates, the P-value is 0.003 and since the p-value is less than 0.05, we reject the null hypothesis (Table 4). So, this result suggests that there is a statistically significant difference in protein content among the different meat samples.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	32	157.49	4.922	2.72	0.003
Error	33	59.66	1.808		
Total	65	217.15			

Table 4. Analysis of Variance

The Tukey method was used to identify which specific groups' means are significantly different from each other. The grouping information with 95% confidence levels provided insight into these differences (Table 5):

Factor	N	Mean	Grouping		
PVC 043. Schl 25	2	28.43	A		
PVC 046. Schl 24	2	27.925	A	B	
PVC 056. Schl 21	2	27.775	A	B	
PVC 052. Schl 23	2	27.070	A	B	
PVC 062. Schl 22	2	26.980	A	B	
PVC 048. Schl 26	2	26.870	A	B	
PVC 014. Schl 23	2	26.775	A	B	
PVC 063. Schl 24	2	26.7400	A	B	
PVC 047. Schl 24	2	26.675	A	B	
PVC 021. Schl 22	2	26.570	A	B	
PVC 066. Schl 20	2	26.530	A	B	
PVC 049. Schl 23	2	26.445	A	B	
PVC 059. Schl 25	2	26.290	A	B	
PVC 055. Schl 23	2	26.2600	A	B	
PERSA Sch.EOEKA HS2_1	2	25.965	A	B	
PVC 020. Schl 25	2	25.935	A	B	
PVC 019. Schl 26	2	25.8700	A	B	
PVC 022. Schl 23	2	25.825	A	B	
PVC 050. Schl 17	2	25.590	A	B	C
PVC 057. Schl 26	2	25.5750	A	B	C
Kottelete Schwein_1	2	25.5700	A	B	C
PVC 060. Schl 19	2	25.555	A	B	C
PVC 045. Schl 21	2	25.55	A	B	C
PVC 005. Schl 22	2	25.530	A	B	C
PVC 058. Schl 27	2	25.490	A	B	C
PVC 006. Schl 27	2	25.2650	A	B	C
PERSA Sch.EOEKA HS2	2	25.25	A	B	C
Kottelete Schwein	2	25.1850	A	B	C
PVC 061. Schl 24	2	25.120	A	B	C
Bio	2	24.190	A	B	C
PVC 064. Schl 20	2	23.40	A	B	C
PVC 065. Schl 18	2	22.46		B	C
Bio_1	2	20.03			C

Table 5. Grouping Information Using the Tukey Method and 95% Confidence

Means that do not share a letter are significantly different.

Group A (Highest Protein Content):

PVC 043. Schl 25: Mean = 28.43%

Significantly higher protein content compared to most other samples.

Indicates high protein quality and could be used as a benchmark for high-protein meats.

Group A/B:

PVC 046. Schl 24, PVC 056. Schl 21, PVC 052. Schl 23, PVC 062. Schl 22, PVC 048. Schl 26, PVC 014. Schl 23, PVC 063. Schl 24, PVC 047. Schl 24, PVC 021. Schl 22, PVC 066. Schl 20, PVC 049. Schl 23, PVC 059. Schl 25, PVC 055. Schl 23, PERSA Sch.EOEKA HS2_1, PVC 020. Schl 25, PVC 019. Schl 26, PVC 022. Schl 23: Means

ranging from 26.445% to 27.925%. High protein content but slightly lower than Group A. Suitable for consumers seeking high-protein diets.

Group A/B/C (Intermediate Protein Content):

PVC 050. Schl 17, PVC 057. Schl 26, Kottelete Schwein_1, PVC 060. Schl 19, PVC 045. Schl 21, PVC 005. Schl 22, PVC 058. Schl 27, PVC 006. Schl 27, PERSA Sch.EOEKA HS2, Kottelete Schwein, PVC 061. Schl 24: Means ranging from 25.120% to 25.965% Moderate protein content. Indicates a consistent level of protein, suitable for general nutritional needs.

Group B/C:

Bio, PVC 064. Schl 20, PVC 065. Schl 18: Means ranging from 22.460% to 24.190%. Lower protein content compared to Groups A and A/B. Could be targeted towards consumers who prefer organic products despite the lower protein content.

Group C (Lowest Protein Content):

Bio_1: Mean = 20.030%

Significantly lower protein content. This may indicate variability within organic products or specific batches that require further quality control (Fig.5).

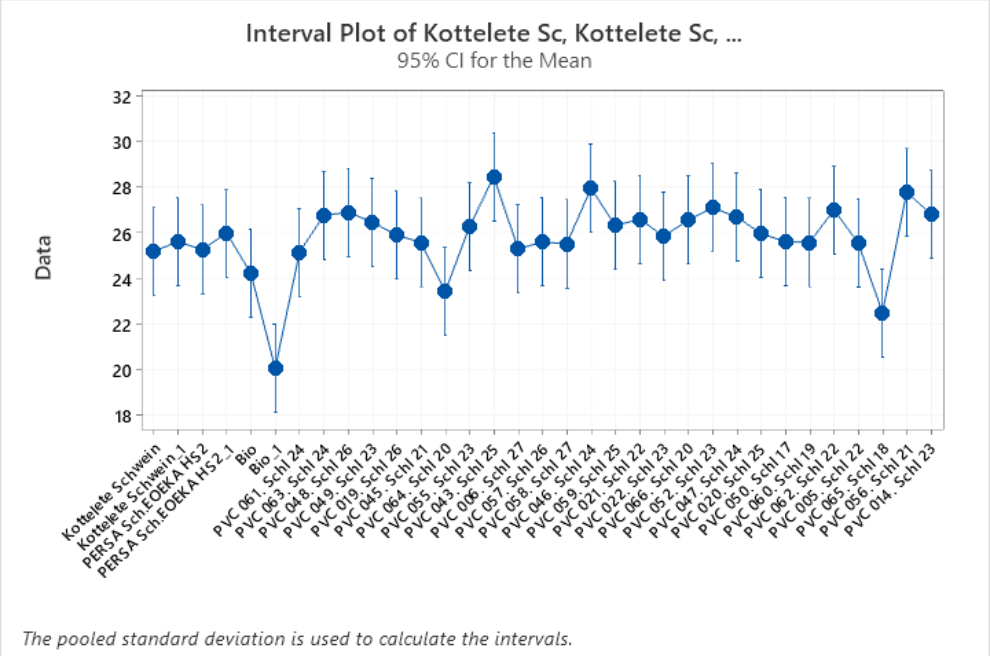

Fig.5 The protein percentage of the samples

The significant differences in protein content between the different meat samples in this investigation are in line with other research's conclusions. Many studies have

shown that the protein level of meat varies depending on many factors, such as the diet, breed, and processing done after the animal is killed.

Variability in Protein Content:

The study conducted by Purchas et al. (2004) which revealed that meat composition may be greatly influenced by factors such animal genetics, feed type, and management techniques, is consistent with the observed heterogeneity in protein concentration across the meat samples. In a similar vein, Wood et al. 2008 noted that breed and dietary variances result in changes in muscle composition, particularly protein content.

High Protein Content:

Prior research confirms that sample PVC 043. Schl 25 (28.43%) has the greatest protein content, as shown by our analysis. For example, it has been demonstrated that high-quality feed and selective breeding techniques increase meat's protein content (Atlante et al., 2020). This is consistent with research by Wood et al. (2008), who found that raising meat protein levels may be achieved by feed optimization.

Intermediate Protein Content:

Samples including PVC 050, Schl 17 (25.59%), and Kottelete Schwein (25.18%) have intermediate protein contents that are similar to the ranges reported in Lonergan et al. 2003. They pointed out that normal commercial processes provide moderate protein levels that satisfy dietary needs in general.

Low Protein Content:

Research on the manufacture of organic meat has led to the reduced protein level seen in samples that are considered organic, such Bio_1 (20.03%). According to Garnier et al. (2002) less intense feeding regimens used in organic farming, which prioritize animal comfort and sustainability, frequently lead to reduced protein content. This confirms our findings and implies that customers are drawn to organic meats because of their additional advantages, even if they may have less protein.

Statistical Significance and Group Differences:

The usage of ANOVA and the Tukey post-hoc test in our research to identify significant differences in protein content is a common approach in meat science research. Studies by Hsu (1996) also used these statistical methods to discern meaningful differences in nutritional content among different food samples, thereby validating our methodological approach for desirable traits, consumer preference analysis, nutritional supplement exploration, and post-slaughter handling technique optimization to further advance the understanding of the meat quality of Husum saddleback pigs.

7.4 PH24 measurement:

A one-way Analysis of Variance (ANOVA) was used to test the null hypothesis that all means of the PH values for the different meat types are equal, against the alternative hypothesis that not all means are equal. The significance level (alpha) was set at 0.05, which means we are willing to accept a 5% chance of rejecting the null hypothesis when it's true. Additionally, The F-value from the ANOVA table is 2.04 with a p-value of 0.028. Since the p-value (0.028) is less than the significance level (0.05), we reject the null hypothesis. This indicates that there is a statistically significant difference in the mean PH values among the different meat types.

Tukey's Honestly Significant Difference (HSD) test was used to identify which specific groups (meat types) have statistically different PH values from each other (Table 6). The results are shown in the "Grouping Information" section. Means that share a letter are not significantly different from each other.

Factor	N	Mean	Grouping	
PERSA Sch.EOEKA HS2	2	5.6500	A	
Bio	2	5.600	A	B
PVC 052. Schl 23	2	5.500	A	B
PVC 066. Schl 20	2	5.500	A	B
PVC 006. Schl 27	2	5.500	A	B
PVC 059. Schl 25	2	5.4500	A	B
PVC 048. Schl 26	2	5.4500	A	B
PVC 020. Schl 25	2	5.4500	A	B
PVC 047. Schl 24	2	5.4500	A	B
PVC 050. Schl 17	2	5.4500	A	B
PVC 064. Schl 20	2	5.4500	A	B
PVC 049. Schl 23	2	5.4500	A	B
PVC 065. Schl 18	2	5.4500	A	B
PVC 046. Schl 24	2	5.4500	A	B
PVC 045. Schl 21	2	5.4500	A	B
PVC 063. Schl 24	2	5.4500	A	B
PVC 014. Schl 25	2	5.4500	A	B
Kottelete Schwein	2	5.4500	A	B
PVC 057. Schl 26	2	5.400	A	B
PVC 022. Schl 23	2	5.400	A	B
PVC 061. Schl 24	2	5.400	A	B
PVC 058. Schl 27	2	5.400	A	B
PVC 021. Schl 22	2	5.400	A	B
PVC 019. Schl 26	2	5.400	A	B
PVC 056. Schl 21	2	5.400	A	B
PVC 005. Schl 22	2	5.3500		B
PVC 055. Schl 23	2	5.3500		B
PVC 043. Schl 25	2	5.3500		B
PVC 062. Schl 22	2	5.3500		B
PVC 060. Schl 19	2	5.3500		B

Table 6. Grouping Information Using the Tukey Method and 95% Confidence

Means that do not share a letter are significantly different.

Detailed Comparisons which is illustrated by Boxplot (Fig 6)

Let's break down the comparison further:

PERSA Sch.EOEKA HS2 (5.6500): This group has the highest pH, indicating potentially different processing or characteristics compared to other groups. It's significantly higher than Group B means.

Bio (5.6000) and other A/B groups: These groups have slightly lower pH values than PERSA Sch.EOEKA HS2 but are not significantly different from each other or PERSA Sch.EOEKA HS2. Their pH values range from 5.400 to 5.600, suggesting they are relatively similar in terms of pH.

Group B (5.3500): These groups have the lowest pH values. The fact that they are significantly different from PERSA Sch. EOEKA HS2 but not from each other or Group A/B groups implies a lower pH trend for these meats.

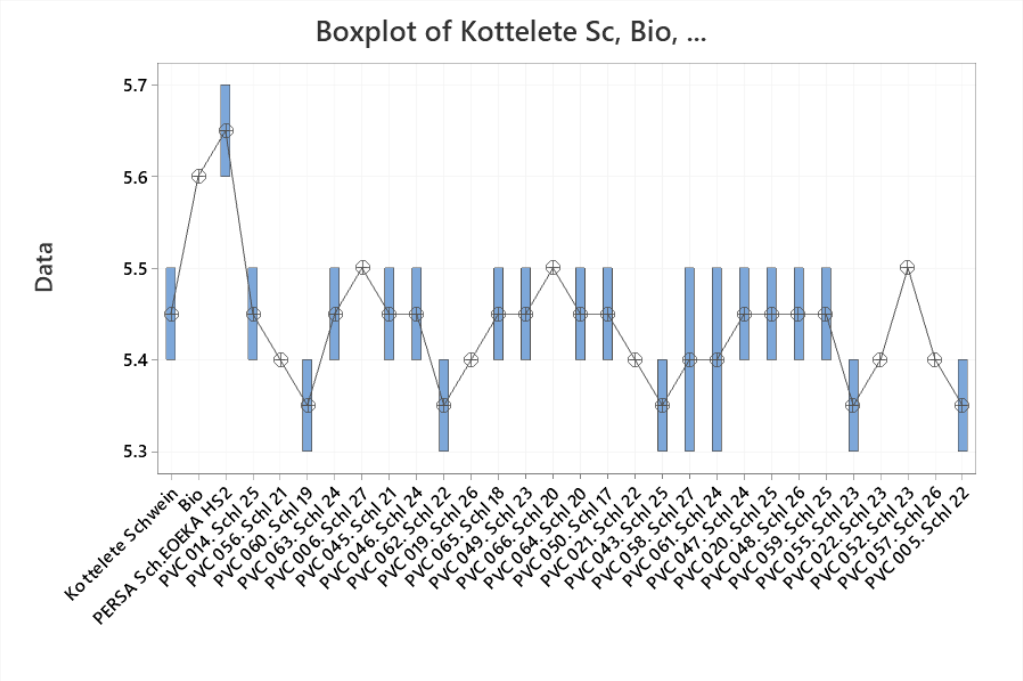

Fig.6 The mean of the PH value of the samples

Practical Implications:

High pH Group (PERSA Sch. EOEKA HS2): Meat with higher pH might have better water-holding capacity and could be more tender, but it could also be more prone to spoilage.

Intermediate pH Group (A/B): These meats have pH values in the middle range, suggesting moderate water-holding capacity and tenderness.

Low pH Group (B): Lower pH meats might have a longer shelf life but could be less tender and drier.

Conclusion: The ANOVA and Tukey HSD test reveals that PERSA Sch. EOEKA HS2 stands out with a significantly higher pH compared to the lowest pH group. Most groups fall into an intermediate category without significant differences among them. This suggests a need to further explore the factors affecting the pH levels in these meats, such as processing methods, type of meat, or other environmental factors.

High pH Group (PERSA Sch.EOEKA HS2):

The group with the highest mean pH (5.6500) was the subject of the study. According to Huff-Lonergan & Lonergan. (2005), meat with a high pH is frequently more delicate and is often associated with better water-holding capacity. Hwang & Thompson. (2000) found a similar correlation between lessened protein denaturation and tender meat and higher pH levels.

Intermediate pH Group (A/B):

The group's pH readings ranged from 5.400 to 5.600, with no discernible variation amongst the samples, according to the study's findings. Meat with balanced quality features usually has an intermediate pH value. Meats with pH levels of about 5.5 often have a reasonable combination of water-holding capacity and shelf life (Jones et al., 1997). This validates our observations that these meats are neither unduly tough nor extremely susceptible to spoiling.

Low pH Group (B):

Study Findings: This group had the lowest pH values (5.3500). Hwang & Thompson. (2000) discusses how meat with low pH levels has a lower ability to keep water and increases drip loss. This supports our observation that there may be less tenderness and dryness in these meats. Further supporting this study, is the finding by (Lonergan et al., 2003) that meat with lower pHs had longer shelf lives because of less microbial activity.

8. Conclusion

The present investigation offers an in-depth examination of many meat quality indices in Husum saddleback pigs, with particular emphasis on characteristics like the amount of intramuscular fat (IMF), meat color, protein content, and ultimate pH (UPH). The findings highlight the unique qualities of saddleback pigs, especially their high IMF content, which improves the sensory qualities of pork. They have less muscular meat overall, yet they are nevertheless important in specialized markets because of their exceptional taste, softness, and juiciness. The feeding schedule is a significant independent variable affecting meat quality in this investigation. The growth, amount of fat deposited, and general quality of the pigs' meat are all highly influenced by the kind and makeup of their diet. To achieve the necessary meat quality qualities,

balanced diets rich in critical nutrients are needed for sustaining the health of the pigs as well as the customer demand for sustainably produced meat.

The results emphasize that rather than concentrating just on lean meat content, new pricing models should be used that take into account the improved meat quality of saddleback pigs. Saddleback pig farming may be sustained by such a strategy, particularly in ecological and organic settings. Future research should concentrate on longitudinal studies of feeding regimens, selective breeding for desirable traits, consumer preference analysis, nutritional supplement exploration, and post-slaughter handling technique optimization to further advance the understanding of the meat quality of Husum saddleback pigs.

In conclusion, specialized feeding programs and marketing techniques, in addition to the preservation and promotion of Husum saddleback pigs, can support the expansion and sustainability of ecological pig farming. This thesis lays the foundation for future studies and useful applications in the meat business by offering insightful information on the characteristics of saddleback pig meat quality.

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