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Effects of thermally treated broiler feed with different organic acid levels on resulting meat composition and parameters related to meat quality

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ABSTRACT

Microbial contaminations of animal feed can lead to impaired food safety and human foodborne diseases. Risks can be mitigated by conventional feed hygienization practices including thermal processing and supplementations with organic acids. The aim of this study was to examine whether these hygienization techniques, alone or in combination, affect meat composition and meat quality-related parameters in broilers. Water, protein and fat contents of broiler breasts were determined using destructive analyses. Additionally, meat color and pH analyses, as well as fluorescence and reflectance analyses in the UV/VIS/NIR range, were conducted using rapid non-invasive methods. Although minor differences were observed regarding fat content, color and pH between the treatment groups, these were ascribed to natural product variations, and no substantial correlation could be established between the diets fed and the parameters examined. It was concluded that the implemented hygienization treatments did not negatively affect broiler meat composition and quality-related parameters.

Industrial relevance: Product–process interactions with respect to food quality along the entire production chain are of high importance. Often data on the impact of feed and feed preparation techniques on the resulting product quality of meat are missing.

The manuscript provides a new and comprehensive study on the effects of thermally treated broiler feed supplemented with organic acids on selected meat parameters. This is the first study using optical together with conventional chemical methods for an analysis of meat changes occurring after feed supplementation.

1. Introduction

Contaminated feed components and finished animal feeds for poultry and other food-producing animals are considered to be important causes of human foodborne diseases (Cox, Bailey, Thomson, & Juven, 1983; Crump, Griffin, & Angulo, 2002; EFSA, 2008). Thermal processing has been shown to improve feed digestibility and to result in reductions of microbial contaminants (Cox, Burdick, Bailey, & Thomson, 1986; König, 1994). However, these reductions are often only marginal and many opportunities exist for cross-contaminations (EFSA, 2008; Veldman, Vahl, Borggreve, & Fuller, 1995). The efficacy of such treatments are influenced by feed components (Doyle & Mazzotta, 2000), water availability (Liu, Snoeyenbos, & Carlson, 1969; Mossel, Van Schothorst, & Kampelmacher, 1967), the level of contamination in the feed, as well as the treatment period (Ricke, 2005a) and treatment temperature (Mossel et al., 1967). In addition to enhancing digestibility and diet palatability, supplementations with organic acids such as propionic and formic acid provide protection against re-contaminations by lowering the pH in feed matrices and subsequently in the proximal parts of the digestive tracts of food-producing animals (Hinton & Linton, 1988; Ricke, 2005b; van Immerseel et al., 2006; Wales, Allen, & Davies, 2010). In the past, livestock and meat producers focused on satisfying the increasing demand for animal protein in human nutrition as well as on securing product safety (Grashorn, 2010). As a result of recent incidences of illness from contaminated foods, product recalls, and the growing awareness of the impacts of farm production practices on the environment and animal welfare, consumer demands for high standards of product quality have sparked the growth of quality assurance schemes in the European meat industry

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(Andersen, Oksbjerg, Young, & Therkildsen, 2005; Bredahl, Northen, Boecker, & Normille, 2001).

Determining the overall quality of meat is challenging as a multitude of parameters must be considered. While meat pH and color can be analyzed relatively simply, the determination of the main constituents water, protein and fat by standard methods is time-consuming and can often not be performed before the highly perishable product should be consumed. Optical non-invasive measurements such as reflectance spectroscopy can present efficient alternatives (Freudenreich, Lautenschläger, & Rödel, 1996). The quality-related parameters color in homogenized pork (Cozzolino, Barlocco, Vadell, Ballesteros, & Gallieta, 2003), beef steaks (Liu et al., 2003) or chicken breasts (Liu & Chen, 2001) and pH in pork *Musculus longissimus dorsi* (Andersen, Borggaard, Rasmussen, & Houmøller, 1999) have been measured using the VIS/NIR spectral range, together with chemometric analyses. Studies have also reported that chemical constituents, including dry matter, crude protein and fat of chicken breasts (Berzaghi, Dalle Zotte, Jansson, & Andrighetto, 2005), essential amino acid content in poultry meal (Fontaine, Hörr, & Schirmer, 2001), as well as moisture and intramuscular fat in homogenized beef *M. longissimus dorsi* (Ripoll, Albertí, Panea, Olleta, & Sañudo, 2008) could be determined using NIRS. Furthermore, the identification of animal meats derived from different species (Cozzolino & Murray, 2004) or between poultry breeds (Ding, Xu, & Chan, 1999) is possible using VIS/NIR reflectance and chemometric analyses, which can also predict, e.g., cooking losses in chicken patties (Chen & Marks, 1998). Additionally, microbial spoilage of chicken meat can be detected using VIS/NIR spectroscopy and chemometrics (Alexandrakis, Downey, & Scannell, 2012; Lin et al., 2004). Fluorescence spectroscopy is a more selective and sensitive technique (Strasburg & Ludescher, 1995) that can determine, e.g., dry matter, fat and protein contents in bovine muscles (Sahar, Boubellouta, Lepetit, & Dufour, 2009), fat contents in pork emulsions (Allais, Viaud, Pierre, & Dufour, 2004), connective tissue contents in ground beef (Wold, Lundby, & Egelandsdal, 1999), as well as lipid oxidation in chicken meat (Gatellier et al., 2007; Olsen et al., 2005; Wold & Mielnik, 2000). A review of the multivariate autofluorescence of multiple intact food systems has been provided by Christensen, Nørgaard, Bro, and Engelsen (2005). Microbial spoilage can be assessed by front-face fluorescence spectroscopy using porphyrins as indicators (Ashby et al., 2003; Fröhling et al., 2012) or synchronous front-face fluorescence spectroscopy and N-PLS regression (Sahar, Boubellouta, & Dufour, 2011).

Within this context, the present study aimed at examining the impact of conventional feed hygienization measures, e.g., thermal processing and chemical supplementations, on the composition and quality-related parameters of broiler meat using destructive analyses and non-invasive spectral analyses, respectively. While some data exists regarding the influence of chemical supplementations in broiler diets on meat yield (Denli, Okan, & Çelik, 2003; Isabel & Santos, 2009; Leeson, Namkung, Antongiovanni, & Lee, 2005), the impact of thermal treatment regimens on meat composition and parameters related to product quality have not yet been elucidated to date. As high temperature feed treatments can lead to a lower body weight gain in broilers (Jones, Anderson, & Ferket, 1995), but the addition of organic acids has been reported to cause higher body weights (Owens, Tucker, Collins, & McCracken, 2008; Roth & Ettle, 2005), the effect of a combination of both treatments on the resulting meat quality is of interest. Furthermore, a comparison between conventional destructive analysis methods and non-destructive spectroscopic analyses was performed.

2. Materials and methods

2.1. Animals, diets and sampling

Male day-old broiler chicks (n = 960, Cobb) were purchased from a commercial hatchery (Cobb Germany Avimex GmbH, Wiesenena-Wiedemar, Germany) and reared in randomly allocated groups of ten in 2.20 × 1.80 m floor pens with softwood shavings for a period of 35 days at the Institute of Animal Nutrition of the Freie Universität Berlin, Germany. Feed and water were provided for ad libitum consumption throughout the growth period. The birds were inspected daily by a veterinarian for signs of disease or injuries and weighed on days 1, 7, 14, 28 and 35. Feed intake was recorded on a weekly basis, and the feed conversion ratio was calculated after correcting for mortalities. In the first week of the trial, the temperature in the stable was maintained at 33 °C, after which it was gradually reduced by 3 °C per week to 24 °C. The air humidity ranged from 21 to 36%. The lighting program consisted of 24 h of light during the first 3 days, 20 h of light during days 4 to 7, and 16 h thereafter.

The experimental diets were formulated to meet the nutritional requirements for poultry according to the Society of Nutrition Physiology (GfE, 1999). Starter and grower diets (Table 1) were fed from days 1 to 21 and from days 22 to 35, respectively. Prior to feeding, the diets were processed using pelleting at 70 °C, long-term conditioning at 85 °C followed by pelleting at 70 °C, or expanding at 110 °C or 130 °C in batches of three per treatment. Of these batches, one was not supplemented with organic acids, whereas one was supplemented with 0.75% and another with 1.5% Lupro-Cid® (BASF SE, Ludwigshafen, Germany), which is comprised of 63.75% formic acid, 25% propionic acid and 11.25% water (Table 2). Each of the twelve experimental diets was fed to birds in eight replicate pens.

On day 35, 32 birds were selected randomly from each diet group and slaughtered by stunning and cervical decapitation. Both breast muscles (*Musculus pectoralis major*) were removed from the carcasses and stored at a temperature of 4 °C for 24 h, after which the raw samples were subjected to analyses at the Department of Horticultural Engineering of the Leibniz Institute for Agricultural Engineering Potsdam-Bornim, Germany.

Animal performance and digestibility data as well as descriptions of the feed hygienization techniques implemented, i.e., thermal processing methods are described in detail in Goodarzi Boroojeni et al. (2014). All procedures involving handling of the animals were approved by the State Office of Health and Social Affairs Berlin (Landesamt für Gesundheit und Soziales Berlin, LaGeSo Reg. Nr. 0113/11).

2.2. Meat composition

The analyses of the water, protein and fat content in the broiler meat samples were conducted on one of the two breast muscles obtained from each animal by random selection.

2.2.1. Water content

Approx. 5 g of meat homogenate was placed into pre-weighed porcelain crucibles. The samples were dried in a compartment drier (Hereus UT 20, Fisher Scientific GmbH, Schwerte, Germany) at 105 °C for 4 h. After drying, the crucibles were put into a desiccator for 1 h and weighed again.

2.2.2. Protein content

The protein content was determined using Büchi Kjeldahl devices (Scrubber B414, Digestion system K-432/438, KjelMaster K375 and Sampler K-376/377, Flawil, Switzerland). About 1 g of meat homogenate was weighed into a digestion tube and treated with 10 mL selenium-containing (10 mM, catalyst) H_2SO_4 (96%, Carl Roth, Karlsruhe, Germany) at 400 °C for 2 h. After digestion, 60 mL NaOH (32%, Carl Roth, Karlsruhe, Germany) was added to the solution for steam distillation (100% steam pressure, 4 min), and the released NH_3 was intercepted in a titration tube with ~50 mL H_3BO_3 (2%, Carl Roth, Karlsruhe, Germany). The intercept solution was re-titrated with H_2SO_4 (0.1 N) to a pH of 4.5 (initial pH of H_3BO_3).