Lipid and fatty acid composition of fresh and cured-cooked breast meat of standard, certified and label chickens

Lipidzusammensetzung und Fettsäuremuster von frischem und von gepökeltem sowie gekochtem Brustfleisch von Standard-, Marken- und Label-Broilern

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Introduction

In France, production and consumption of chicken meat has for some years been increasing to the detriment of other meat-based products (Devine, 1997). At the same time, the broiler meat industry developed several chicken production systems (standard, certified, label). Moreover, the market for portions and further processed meat products rapidly increased at the expense of whole carcass sales. Standard production uses fast-growing and high meat yield birds which are slaughtered at 6-7 weeks of age, while label production uses slow-growing strains slaughtered at 12 weeks of age. Label chickens are fed diets containing high amounts of cereals and are reared under low density and have access to open air (Sauveur, 1997). The certified chicken is a crossbreed of a standard and a label chicken which has a medium growth rate and is slaughtered at 8 or 9 weeks of age.

The fatty acid composition of muscle lipids in poultry generally reflects the fatty acid composition of the diet (Lessire, 2001). Girard et al. (1993) and Culioli et al. (1990, 1994) demonstrated that it was possible to discriminate the breast meat of standard and label chickens on the basis of their fatty acid profile. Polyunsaturated fatty acid (PUFA) content was higher, whereas that of monounsaturated fatty acids (MUFA) was lower in label chicken breast meat than in standard chickens. These differences were essentially due to the diets of label chickens which contained higher amounts of PUFA, mainly provided by soybean, sunflower or rape seed oils, than the diets of standard chickens which mainly contained tallow. Rabot (1998) compared label and standard chickens which received diets containing mainly raw material of vegetable origin. Analysis of fatty acid profiles of the total lipids in their meat showed that in this case the saturated fatty acid (SFA) and MUFA content was lower (28.7% and 38.4% versus 33.5% and 49.4% in breast meat, 28.1% and 38.7% versus 33.0% and 48.9% in thigh meat, respectively) and PUFA content was higher (32.9% versus 17.2% in breast meat and 33.2% versus 18.1% in thigh meat, respectively) in the meat of standard chickens. Raw materials of animal origin have been totally prohibited in poultry food in France since November 2000. We can therefore expect that fatty acid profiles of label and standard meat have changed since the studies of Girard et al. (1993) and Culioli et al. (1990, 1994). Is it now possible to discriminate between these different production systems on the basis of the lipid content and composition of their meat?

The aim of this study was therefore to re-evaluate the lipid content and lipid composition of breast meat in standard and label chickens, to evaluate the lipid and fatty acid composition in breast meat of certified chicken as a recent product in France, and also to characterize the lipid composition of their cured-cooked meat products for which no results were available up to now.

Materials and methods

Animals and diets

Male chickens of commercial origin (Hubbard-Isa) from a fast (standard), a medium (certified) and a slow-growing line (label) were reared in a conventional poultry house at the Station de Recherches Avicoles (Nouzilly, France) according to the breeder’s recommendation for feeds for label, certified and standard chickens (Quentin et al., 2003). The composition and characteristics of label, certified and standard diets are presented on Table 1. Diet samples were kept at 4°C until lipid analysis. Feed and water were provided ad libitum throughout the growth period. Label birds had no access to open air. Standard chickens were slaughtered at 6 or 7 weeks of age, certified chickens at 8 weeks and label chickens at 12 weeks (80 birds for each category). Birds were chosen randomly. For each group, 16 samples of Pectoralis major (breast) muscle were collected fifteen minutes after death and stored at -20°C until determination of chemical composition. After 24 h storage at -4°C, the right breast muscle and the right leg (thigh plus drumstick) were excised on 64 birds for each category, vacuum-packed and stored at -20°C until processing. After thawing, meat from breasts and legs were processed (ADIV, Clermont-Ferrand, France) into white cured-cooked meat and ham, respectively, under industrial conditions. Therefore, we were able to make only one loaf per muscle type and per group. Breasts were manually lacerated and cured with brine containing 17.6% sodium nitrite, 7.67% dextrose, 2.20% carraghenan, and 0.33% sodium ascorbate (w:v). After deboning and skin removal, leg meat was also manually lacerated and then cured by injection with brine containing 17.6% sodium nitrite, 9.90% dextrose, and 0.30% sodium ascorbate (w:v). Brine was

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Table 1. Composition and characteristics of experimental diets of label, certified and standard chickens

<table>
<thead>
<tr>
<th>Ingredients (g/kg)</th>
<th>Label 0-3 weeks</th>
<th>3-8 weeks</th>
<th>8-12 weeks</th>
<th>Certified 0-1 weeks</th>
<th>1-3 weeks</th>
<th>3-6 weeks</th>
<th>6-8 weeks</th>
<th>Standard 0-1 weeks</th>
<th>1-3 weeks</th>
<th>3-6 weeks</th>
<th>6-7 weeks</th>
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<tbody>
<tr>
<td>Corn</td>
<td>311.5</td>
<td>190.0</td>
<td>332.0</td>
<td>335.0</td>
<td>355.0</td>
<td>300.0</td>
<td>656.2</td>
<td>334.8</td>
<td>415.9</td>
<td>426.2</td>
<td>576.0</td>
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<tr>
<td>Wheat</td>
<td>315.0</td>
<td>560.0</td>
<td>437.0</td>
<td>295.0</td>
<td>300.0</td>
<td>368.7</td>
<td>-</td>
<td>245.0</td>
<td>200.0</td>
<td>150.0</td>
<td>-</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>280.0</td>
<td>197.9</td>
<td>181.6</td>
<td>311.9</td>
<td>287.7</td>
<td>260.0</td>
<td>220.0</td>
<td>350.0</td>
<td>310.0</td>
<td>242.0</td>
<td>196.1</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>40.0</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Soybean toast</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60.0</td>
<td>-</td>
<td>100.0</td>
<td>142.0</td>
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<tr>
<td>Colza oil</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>12.0</td>
<td>15.0</td>
<td>30.0</td>
<td>24.0</td>
<td>25.0</td>
<td>32.0</td>
<td>43.0</td>
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<td>Calcium carbonate</td>
<td>12.0</td>
<td>14.0</td>
<td>14.0</td>
<td>13.2</td>
<td>12.5</td>
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<tr>
<td>Dicalcium Phosphate</td>
<td>18.7</td>
<td>14.7</td>
<td>13.5</td>
<td>19.5</td>
<td>17.0</td>
<td>17.0</td>
<td>17.5</td>
<td>20.0</td>
<td>19.0</td>
<td>18.0</td>
<td>17.5</td>
</tr>
<tr>
<td>L-Lysine</td>
<td>1.0</td>
<td>1.9</td>
<td>0.6</td>
<td>1.5</td>
<td>1.0</td>
<td>0.9</td>
<td>-</td>
<td>0.9</td>
<td>1.0</td>
<td>-</td>
<td>0.6</td>
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<tr>
<td>DL-Methionine</td>
<td>1.8</td>
<td>1.5</td>
<td>1.3</td>
<td>1.9</td>
<td>1.8</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.7</td>
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<tr>
<td>Vitamin and mineral supplement</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
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<tr>
<td>Metabolizable energy, MJ/kg *</td>
<td>11.7</td>
<td>12.1</td>
<td>12.3</td>
<td>11.9</td>
<td>12.1</td>
<td>12.5</td>
<td>13.0</td>
<td>12.1</td>
<td>12.5</td>
<td>13.2</td>
<td>13.6</td>
</tr>
<tr>
<td>Crude protein (g/kg) *</td>
<td>201.0</td>
<td>175.0</td>
<td>165.0</td>
<td>209.9</td>
<td>200.7</td>
<td>191.0</td>
<td>181.2</td>
<td>221.1</td>
<td>204.8</td>
<td>200.8</td>
<td>190.2</td>
</tr>
<tr>
<td>Lipid content (g/kg)</td>
<td>35.3</td>
<td>29.2</td>
<td>37.3</td>
<td>35.5</td>
<td>38.7</td>
<td>45.9</td>
<td>71.4</td>
<td>46.1</td>
<td>50.4</td>
<td>81.2</td>
<td>92.8</td>
</tr>
</tbody>
</table>

Fatty acid profile (% of total fatty acids)

SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; * Calculated value. Composition of premix (per kg of feed): vitamins A (10 000 UI), D3 (2 000 UI), E (30 mg), B1 (1.5 mg), K3 (2 mg), B2 (4 mg), B6 (2.5 mg), B12 (0.015 mg), calcium pantothenate (10 mg), folic acid (0.4 mg), biotin (0.2 mg), cholin (500 mg), nicotinic acid (30 mg), cobalt (0.6 mg), copper (20 mg), iron (50 mg), iodine (1 mg), manganese (85 mg), selenium (0.25 mg), zinc (60 mg). The starter feeds were presented as mash and the other feeds were steam pelleted (diameter 2.5 mm)

injected at a ratio of 10% of the fresh meat weight. Both types of cured meat were vacuum-tumbled at 4°C for 30 min at 7 rotations per min then for 10 h in alternating 5 minutes tumbling at 7 rotations per min and 10 min stopping periods. Tumbled meat was vacuum-packed, cooked until a core temperature of 66°C was reached and cooled at 0°C for 24 h.

Chemical analysis

Dry matter of fresh breast and cured-cooked meat was determined according to AOAC (1984). The protein content was measured with the Kjeldhal copper catalyst method (AOAC, 1984). Total lipids were extracted quantitatively by homogenizing a sample of minced tissue in chloroform/methanol 2/1 (v/v) (FOLCH et al., 1957). Total lipids were quantified gravimetrically. The classes of lipids and phospholipids were only determined in cured-cooked products as in fresh meat many data are available in the literature. We used an iatroscan (Iatron, Tokyo, Japan) based on thin-layer chromatography and a flame-ionisation-detector system (TLC-FID) with 10 silica-gel thin layer chromatography rods according to MARES et al. (1983). The hydrogen flow rate was 160 ml/min, the air flow rate 21/min, the scanning speed 0.3 cm/s. The software (Boreal, JMBS Development, Grenoble, France) recorded chromatograms and integrated peaks with reference to an external standard (Sigma Chemical Co, St Louis, MO, USA). Fatty acid composition was determined after transmethylation (MORRISON and SMITH, 1964) by gas chromatography (Perkin Elmer, Saint Quentin en Yvelines, France). Injector and detector (FID) temperatures were set at 250°C, the carrier gas was nitrogen with a head column pressure of 16.5 psi. We used a capillary column (BPX70, SGE, Villeneuve St Georgues, France). Methyl esters were identified and quantified by comparison with standards (Supelco 37 Component FAME Mix, Sigma, Saint Quentin Fallavier, France).

Statistical analysis

All data were expressed as means and residual standard errors. A one-way analysis of variance was used to test the effects of the production system on all criteria measured (General Linear Model procedure of SAS, 1989).

Results

Chemical composition of diets

The lipid content in feed increased with the age and energy requirements of the animals (Table 1); there was a two-fold increase between the first and the last periods for standard and certified diets. The major decrease in lipid content in the growing-label diet resulted from the replacement of corn by wheat. The standard diets contained the highest lipid and MUFA content and the label diets the lowest lipid content and highest SFA and PUFA content. For label and standard diets, the fatty acid composition was comparable for the different periods. For all diets, the main fatty acids were palmitic (C16:0), oleic (C18:1) and linoleic (C18:2) acids for SFA, MUFA and PUFA, respectively (data not shown).
Chemical and fatty acid composition of breast muscle

In breast muscle, lipid content was highest for 7-week-old standard chickens and lowest for certified chickens (Table 2). Dry matter and protein content was highest for label chickens and lowest for standard chickens. The protein in breast muscle was positively correlated with dry matter content ($r = 0.63$, $p < 0.05$). Correlations between lipid and protein or dry matter content were not significant.

The breast muscles of label and certified chickens had the highest percentage of SFA, particularly palmitic acid (Table 2). The percentage of MUFA was highest (palmitoleic and oleic acids) in label chicken breast meat, and lowest in the certified chicken breast meat. The percentage of PUFA was highest for standard birds and lowest for label birds. Slaughtering standard chickens at 7 weeks instead of 6 weeks did not markedly affect fatty acid composition.

Chemical and fatty acid composition of cured-cooked breast meat

The differences in protein and dry matter content between chicken types in cured-cooked breast were the same as in fresh meat (Table 3), but the curing-cooking process resulted in an increase in dry matter content (+ 4% in average) and a decrease in protein content (- 9%) in the final products. Lipid content increased (+ 28%) for the 7-week old standard, certified and label chickens. For the cured-cooked breasts of 6-week-old standard chickens, it decreased (- 8%). Cured-cooked breast meat of these birds also presented the lowest lipid, triglyceride and cholesterol content but the highest phospholipid content. Phosphatidic acid (PA), diphosphoglycerides (DPG) and phosphatidyl-choline (PC) were the major components of the phospholipid fraction. Cured-cooked breasts of label chickens exhibited the highest PC content and lowest DPG + PA levels. By contrast, cured-cooked breasts of 7-week old standard birds exhibited the lowest PC content and highest DPG + PA content.

The processing of breast muscle into cured-cooked white meat resulted in a decrease in PUFA, with concomitant increases in SFA (C16:0) and MUFA (C18:1), particularly in standard and certified birds (Tables 2 and 4). Almost all long chain PUFA decreased and the ratio between n-6 and n-3 fatty acids increased considerably with curing-cooking.
The ham produced from label chicken leg meat exhibited the highest levels of dry matter and protein and the lowest levels of lipids (Table 5). This product also had the low-
est triglyceride and cholesterol content. The ham produced from 7-week-old standard chickens had the highest lipid, triglyceride and phospholipid content. The ham had lower protein content and much higher lipid (3.5 to 4.9 fold depending on the group) and triglyceride (5.0 to 13.1 fold depending on the group) content than cured-cooked breast meat (Table 3 and 5). Moreover, it exhibited higher amounts of phospholipids and cholesterol (2.5 to 8.2 fold depending on the group). Phosphatidic acid (PA) and di-phosphoglycerides (DPG) were the major components of the phospholipid fraction. The ham of 7-week-old standard chickens exhibited the highest amounts of DPG + PA and phosphatidyl-ethanolamine (PE) and the lowest amount of PC. The ham of certified chickens presented the highest amount of PC. Hams presented much higher levels of DPG + PA and lower levels of PC than cured-cooked breast meat.

The ham of label chickens had the highest SFA (C18:0) content and the lowest PUFA (C18:2 and C18:3) content (Table 6). By contrast, the ham produced from 7-week-old standard chicken legs contained the lowest SFA and highest PUFA content. Except for label chickens, hams presented lower levels of SFA and higher levels of PUFA than white cured-cooked meat. As for the cured-cooked breast meat, we could not detect long chain fatty acids in hams.

Discussion

Lipid content and composition can greatly influence meat quality attributes (dietetic, sensory and storage life). This study investigated the lipid composition of fresh and processed meat of the three main chicken types produced in France (standard, certified and label). Standard chickens which exhibit the highest abdominal fatness (BEBR, et al, 2002) also presented the highest lipid content in breast muscle. The breasts of certified and label chickens, which are medium- and slow-growing chicken types, respectively, contained lower amounts of lipids. Our results are in agreement with those of Kim (1989), Culjoli et al. (1990), Girard et al. (1993) and Rabot et al. (1999) who all reported that breast and leg muscle from label chickens exhibited lower lipid content. The difference between the two chicken types was mainly explained by a difference in triglyceride deposition (Kim, 1989). According to Marion (1965), Grey et al. (1983) and Hamm et al. (1984) after 5 weeks increasing age leads to a decrease in lipid content of chicken breast muscle which could explain the difference observed in our study. We also confirmed the increase in dry matter and protein content of muscle with age, as already reported by Singh and Essary (1974) and Grey et al. (1983), probably due to the increase of muscle fiber size.

Analysis of the fatty acid profile of the breast muscle lipids was consistent with the results obtained by Rabot (1998). Breast muscle of standard chickens exhibited the highest PUFA content, and breast muscle of label chickens the highest SFA and MUFA content. This was also consistent with the fact that diets for standard chickens provided higher quantities of PUFA than diets for label chickens (for instance, 92.8 vs 37.3 g of lipids per kg in the finishing diet, respectively). Moreover, feed consumption was higher for standard birds compared to other chicken types (QUENTIN, et al, 2003). Finally, because of the high consumption of PUFA, the hepatic lipid metabolism of standard birds was probably inhibited, thus leading to direct deposition of dietary PUFA in muscles (LESSIRE, 2001) to the expense of MUFA neo-synthesized in liver.

For processed products, we only had one repetition per muscle type per group. Therefore, we will present in the following text only tendencies. Some of the water and water soluble proteins were eliminated with the cooking juice during processing, resulting in an increase in dry matter and lipid content in processed meat. We did not measure the proportions of the different lipid classes in fresh meat, but Rabot (1998) reported average values of 7.0, 6.3 and 0.5 g/kg for triglycerides, phospholipids and cholesterol, respectively, in breast muscle and 30.0, 8.4 and 0.91 g/kg in leg muscles of standard chicken. It seems that the curing process slightly affected lipid classes. By contrast, the phospholipid classes were substantially modified by processing. The main phospholipids in fresh muscles are PE and PC (Marion and Miller, 1968; Rabot, 1998). Some of the sphingomyelin (SM), PE and lyso-phosphatidyl-choline (LPC) disappeared in cured-cooked meat, to the benefit of DPG and PA, probably because of the mechanical and thermal treatments used during processing. Fatty acid composition was also considerably affected by processing for standard and certified chickens. Long chain fatty acids were not detected, with the result that processed products were probably less susceptible to oxidation than fresh meat. Moreover, the difference between chicken types observed for fresh meat were less pronounced for processed meat. In the case of label chicken breast, we found a weaker effect of processing on fatty acid composition of meat. It is likely that the integrity of cell membranes rich in PUFA may be less sensitive to processing because of better protection by the less soluble connective tissue. Indeed, Culjoli et al. (1990) showed that collagen solubility was lower in breast meat of label chickens than in that of standard chickens. Moreover, the levels of DPG + PA were lower in cured-cooked breast meat of label chickens, which is in agreement with the greater resistance of label meat to mechanical and thermal treatments. Finally, the process resulted in an increase in the n-6/n-3 ratio of fatty acids which is not beneficial for human health according to ANC recommendations (2001).

Lipid and triglyceride content in ham were much higher than in cured-cooked breast. This is in accordance with the higher lipid content of red poultry muscles. Indeed, Rabot (1998) reported a ratio of 3.17 between thigh and breast for total lipid content after cooking. Moreover, in our study hams were prepared with intra- and inter-muscular fatty tissue while cured-cooked breasts only contained intra-muscular fat. The phospholipid and cholesterol content was also higher in hams than in cured-cooked breasts. Leg muscles contain red fibers which are smaller in size than white fibers. The levels of structural lipids are therefore higher in leg muscles than in white muscles (SMITH, et al, 1993). Structural lipids contain mainly PUFA. Hams therefore exhibited higher PUFA content than cured-cooked breast and certainly a greater susceptibility to oxidation. Protein content was lower in ham than in cured-cooked breast. This can be related to the much lower protein content of leg muscles reported by Rabot (1998), average values for breast and leg muscles being 223 and 184 g/kg, respectively.

The lipid content of cured-cooked breast of chickens is lower than that of pork (12 to 17 vs 30 to 53 g/kg, Favier et al., 1995; Gandermer, 2002) and the lipid content of chicken hams is higher (52 to 82 g/kg). The fatty acid composition of cured-cooked chicken meat is similar to that of pork ham. There is little published information on poultry processed products. Li et al. (2002) reported that chicken hot dog and chicken luncheon meat had very high lipid content (132 and 144 g/kg, respectively) because of a lipid supplementation during processing. SFA content was lower for these products (23.1 and 24.3%, respectively) and PUFA content was higher (28.6 and 26.8%, respectively) than in the cured-cooked chicken meat analyzed in our
study. ARAUJO DE VIZCARRONDO and MARTIN (1997) also found high levels of total lipids and PUFA in chicken sausages (135.2 g/kg and 25.12%, respectively).

The lipid content of chicken breast meat is low for all chicken types which is quite interesting from a dietary point of view. The prohibition of raw materials of animal origin has changed the fatty acid profile of standard chicken meat, which now contains more PUFA and lower levels of SFA than label meat and probably decreased the sensory differences observed in past studies between these products. The curing-cooking process resulted in an increase in lipid and MUFA content and reduced the PUFA content of breast meat with the result that processed products were probably less susceptible to oxidation than fresh meat. Moreover, it resulted in an increase in the n-6/n-3 ratio of fatty acids which is not beneficial for human health. The label chickens in our study had no access to open air. Our results should therefore be confirmed by considering this aspect. It would also be interesting to study the influence of production systems on other processed products.

Acknowledgements

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Summary

In France, the main systems of poultry meat production are standard, label and certified. Standard production uses fast-growing and high meat yield birds which are slaughtered at 6 - 7 weeks of age, while label production uses slow-growing strains slaughtered at 12 weeks of age. The certified chicken is a crossbreed of a standard and a label strain which has a medium growth rate and is slaughtered at 8 or 9 weeks of age. As lipids have a major influence on the sensory properties of meat we studied the possibility to discriminate between these production systems on the basis of lipid content and composition in their meat. Therefore, the aim of this study was to analyse the influence of production system on lipid content and fatty acid composition of fresh breast muscle and cured-cooked meat of breast and leg muscles of chickens and to determine the lipid and phospholipid classes of these processed products.

Breasts of label chickens exhibited significantly lower lipid and poly-unsaturated fatty acid (PUFA) content than breasts of standard chickens. By contrast, their mono-unsaturated (MUFA) and saturated fatty acid (SFA) content was significantly higher. After curing-cooking breast meat had increased lipid, MUFA and SFA content and decreased PUFA content. Concerning lipid content and composition, the differences observed between chicken types for fresh meat were reduced in processed products. Cured-cooked meat of leg muscles exhibited higher lipid, triglyceride and PUFA content than cured-cooked meat of breast muscles.

Key words

Chicken, meat, ham, lipids, fatty acids

Zusammenfassung

Lipidzusammensetzung und Fett säuremuster von frischem und von gepökeltm sowie gekochtem Brustfleisch von Standard-, Marken- und Label-Broilern


Stichworte

Huhn, Fleisch, Schinken, Lipide, Fettsäuiren

References


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