This study finds that French pork loins are weakly marbled (low in intramuscular fat). According to the season, 5–15% of loins scored 3 or more on the US NPPC visual rating scale (1–10). An expert panel obtained the same marbling results by visual inspection of fresh cuts. An appreciable improvement in taste was observed as loin score went from 1 and 2 to 3 (lipid mouthfeel increased significantly, although neither juiciness nor flavour were significantly enhanced). As loins scoring 4 and more (NPPC scale) were in short supply, we were unable to demonstrate any more marked positive effect of strong marbling on taste appraisal by the expert panel. The sensory ratings assigned by the expert panel were low on a 0–10 scale, evidence that sensory quality is not emphasized in the French pork industry, but instead nutritional value and appearance for the consumer (no visible fat and even-coloured loin).

The use of NIR technology with a probe developed by IFIP to sort the most strongly marbled loins in the cutting room is promising but requires adaptation.

Améliorer la qualité sensorielle des viandes fraîches de porc par un tri sur la variabilité du gras intramusculaire de la longe

Cette étude fait le constat en France que les longes de porc sont très peu persillées (peu de gras intramusculaire). Selon la saison entre 5 à 15 % des longes présentent une note de persillé supérieure ou égale à 3 sur la grille visuelle de notation américaine NPPC (échelle de 1 à 10). Un jury expert retrouve visuellement cette échelle de notation du persillé sur la côte présentée en frais. On observe une amélioration gustative très sensible à mesurer que les longes passent des notes 1 et 2 à la note 3 (la lipidité en bouche augmente de façon significative, la jutosité et la flaveur ne sont pas significativement augmentées cependant). Faute de longes en note 4 et plus (grille NPPC), nous n'avons vraisemblablement pas pu exprimer un effet marqué du gras persillé sur une perception gustative très supérieure par le jury expert. Les notes sensorielles attribuées par le jury expert sont faibles sur une échelle de 0 à 10 signent que la qualité sensorielle n'est pas mise en avant aujourd'hui dans la filière française au profit de la qualité nutritionnelle et visuelle pour le consommateur (absence de gras et couleur homogène de la longe).

L'utilisation de la technologie NIR (sonde proche infrarouge) mise au point par l'IFIP pour trier les longes les plus persillées en salle de découpe est promiseuse moyennant des adaptations.

Keywords: intramuscular fat, Near InfraRed Spectroscopy, NPPC Scale

Mots clés : gras intramusculaire, qualité sensorielle, sonde proche infra rouge, échelle NPPC
Introduction

Pork loin products (chops, roasts, etc.) are faulted for their dry texture, lack of juiciness and uneven tenderness. The fresh pork meat currently offered to the consumer cannot maintain a steady sensory quality and is largely commoditized.

We know that the cooked ham market, which predominates in France (250,000 t), steers pig production towards lean animals with narrow conformity. In parallel to these hams intended for processing into cooked ham products, we note a reduction of intramuscular fat in the different cuts, including loin, sold essentially as fresh meat.

There is, however, some variability in the fat composition of carcases (effects of genetics, sex and husbandry, and feeding (Lebret et al., 2006)). According to the IFIP observatory of national pig classification, levels of muscle in carcases measured according to predictors of muscle thickness M3 of the loin, and thickness of backfat G3 range from 56% to 65%.

This variability in carcase fat allows some meat to be supplied for pork products that are richer in fat, e.g. dried sausage and dried ham. It is thus probable that certain loin meats in the current population present higher intramuscular fat (IMF) contents.

Intramuscular fat content is a criterion of enhanced sensory quality of fresh pork (Fernandez and Monin 1999, Chevillon et al., 2008, Faucitano et al., 2003). If these meats could be identified and sorted, then their sensory differentiation could help them be more gainfully monetized.

Intramuscular fat content is fairly easy to measure by chemical laboratory analysis, and more recently by instantaneous physical measurement using visible and near-infrared spectroscopy (NIRS), a method that could be deployed in the meat industry and in cutting rooms (as already seen in the dairy industry). These NIRS instruments need first to be calibrated.

The primary objective of this study was to evaluate IMF variability in the domestic production of pork loin, and to determine the fat levels above which an expert panel can make a sensory differentiation. The next step was to evaluate whether this variability was sufficient, and whether current production would allow a segmentation of the fresh meat market based on a sensory criterion, namely IMF content.

A secondary objective was to estimate the feasibility of industrial sorting of meats according to their IMF content using an NIRS-type instrument.

Materials and methods

The project was conducted in a large slaughterhouse processing pork loins from varied production sources (standard pork, quality-label pork, organic pork, omega-3 pork in the Bleu Blanc Coeur chain, certified pork, etc.) and is in two parts.

Evaluation of distribution of loins in an industrial slaughterhouse according to two visual rating scales for intramuscular fat

A literature search for methods to evaluate intramuscular fat in a cutting shop led us to use two available standard rating scales. These were the US NPPC scale (marbling score from 1 to 10) and the Canadian scale of Canada Pork International (CPI: score from 1 to 6). The final aim was to successfully classify pork ribs into four groups by visual differentiation

- 1 Very Lean: IMF content less than 1.5%
- 2 Lean: IMF content between 1.5% and 2.5%
- 3 Medium: IMF content between 2.5% and 3.5%
- 4 Fat: IMF content above 3.5% (fairly rare in France because the trend is to favour genetics for the production of very lean pigs for the cooked ham industry).

A comparison of the two North American scales on some 400 carcases enabled us to assess which scale was best suited to cutting rooms.

Scoring was done by three testers.

On these 400 loins, we also undertook to measure other effects that the slaughterhouse wished to address but that were not in the starting protocol, and which proved important in the subsequent sorting approach:

- The effect of carcase muscle content on IMF content;
- The sex effect (castrated male versus female);
- The carcase weight effect;
- The combined effects conducive to strong marbling: weight * sex * muscle content

After this phase IFIP retained the better-performing US standard sorting scale for the rest of the study.

Chemical, sensory and NIRS characterization of meats in each intramuscular fat class

The characterization tests for each sorting class of intramuscular fat were carried out allowing for the industrial constraints of the slaughterhouse-cutting room in three measurement campaigns. In each campaign, 150 randomly sampled loins and 50 loins taken from heavy carcases, which were higher in fat (lower in muscle) were cut to seek carcases
on the US NPPC scale). The following characteristics were evaluated for each of the three classes of IMF.

On fresh meat before cooking:
- Measurement using an IFIP near-infrared (NIR) probe on 300 loins in Classes 1 to 3. Analysis of spectra and development by IFIP from sorting by NIR probe
- Analysis of intramuscular fat measured in the laboratory using the reference method of Folch, Lees, and Sloane-Stanley.

On cooked meat:
- Cooking for texture measurements: vacuum-packed samples were steamed (surrounding temperature 78 °C, final core temperature 75 °C, cooling in cold room to +3 °C, determination of cooking losses).
- The tenderness of the cooked meat was determined by the method of Warner Bratzler: measurement of maximum shearing force (F in newtons) obtained on a sample disk of diameter 15 mm taken parallel to the muscle fibres, so that the shearing was at right angles to them.
- Tasting by a panel of 12 experts trained at the IDELE laboratory of Villers-Bocage (Calvados) of the three classes on loin sorted at cutting. A total of eight tastings of the three classes of loin were organized by IDELE. The IDELE meat panel of 12 experts attended two training sessions beforehand.

Results

Distribution of loins according to the US NPPC marbling scale in winter

The distribution according to the NPPC scale is shown in Graph 1 below: 75% of the loins scored 1 and 2 had very weak marbling. Some 20% scored 3, i.e. had clearly visible marbling. We found only 3% of loins on average in Class 4, and none in Classes 5 or 6. Some Asian clients buy loins from a score of 4 on the NPPC scale. Our initial objective, which was to use an expert panel to sort four distinct classes of marbling intensity was limited by the available raw materials in French slaughterhouses: French loins are weakly marbled and very lean in appearance.

At the request of the slaughterhouse, we measured the sex effect on marbling ratings of loins (Graph 2). On average, castrated males had more fat and presented loins with higher marbling scores.

On average we observed higher marbling scores as carcase weight increased (Graph 3).

Grille NPPC américaine retenue

with high IMF contents. No Class 4 could be found in any of the 600 loins cut. We thus restricted our study to the differences between three marbling classes (scoring 1, 2 and 3 on the US NPPC scale).

On average we observed higher marbling scores as carcase weight increased (Graph 3).
Accordingly, in the rest of the study, we opted to make sensory comparisons only on loins scoring 1, 2 and 3 available in France, as loins scoring 4 and more were very scarce.

Chemical, technological, sensory and NIRS characterization of meats from three intramuscular fat classes scoring 1, 2 and 3

The second part of the study was conducted during the summer of 2014. No loins scored 4 when rated blind by three IFIP operators. We could therefore only compare loins scoring 1, 2 and 3 for marbling in this study. The distribution is shown in Graph 6 below.

In this period of summer 2014 we observed only 4% of loins scoring 3, i.e. only the loins necessary to make a sensory comparison by the IDELE expert panel of three classes of loin (scoring 1, 2 and 3).

Distribution of chemical IMF values according to batches scoring 1-2-3 on the NPPC scale

We noted a discernible increase in the IMF percentage measured in the loin between scores 1 and 2, and score 3 (Graph 7).
The difference between the averages of scores 1, 2 and 3 was statistically significant (Table 1).

**Table 1: Means and standard deviations for IMF in the three batches. Significant effect of batch on IMF**

<table>
<thead>
<tr>
<th>NPPC marbling score</th>
<th>BATCH 1</th>
<th>BATCH 2</th>
<th>BATCH 3</th>
<th>Significant difference (Analysis of variance GLM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCORE 1</td>
<td>0.77a</td>
<td>1.48b</td>
<td>2.37c</td>
<td>***</td>
</tr>
<tr>
<td>SCORE 2</td>
<td>(0.49)</td>
<td>(0.81)</td>
<td>(0.87)</td>
<td></td>
</tr>
<tr>
<td>SCORE 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***the differences between means are significant at an error rate of 0.1%; abc, means assigned different letters are significantly different at an error rate of 5%; () standard deviation

We thus demonstrate a certain average reliability in the US NPPC rating scale used by the IFIP operators on loins at the cutting stage, although the analysis of Graph 6 shows that IMF values overlap between scores 1, 2 and 3. There was less overlap between extreme marbling scores 1 and 3. Hence we can conclude that the visual rating on the NPPC scale satisfactorily sorts loins with weak marbling from those with strong marbling.

Characteristics of cooked meats (cooking losses and tenderness test by measurement of shearing force)

Nine loins per batch were evaluated for cooking losses (%) and shearing force (in newtons).

No statistically significant differences were found between the three NPPC marbling scores 1, 2 and 3 for these two quality criteria (Table 2). The standard deviations were high, showing that other factors play a role in cooking losses (genetic factor and sensitivity to stress (halothane gene) that were not controlled in this study, uncontrolled post-slaughter stress, ultimate pH standardized between the three lots by slaughter day, etc.).

**Sensory analysis by an IDELE expert panel**

Our primary aim was to determine whether the three batches were differentiated by sensory analysis.

The sensory descriptors were: marbling observed visually on the pork cut before cooking, and then after cooking, lipid mouthfeel, tenderness, flavour and juiciness.

Statistical ANOVA results (Table 3) show that the products differed highly significantly in marbling observed before cooking between the three batches (error rate < 0.1%) and

**Table 2: Means and standard deviations for cooking losses and shearing force of loin in the three batches**

<table>
<thead>
<tr>
<th>NPPC marbling score</th>
<th>BATCH 1</th>
<th>BATCH 2</th>
<th>BATCH 3</th>
<th>Significant difference (Analysis of variance GLM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooking losses from loin (%)</td>
<td>17.45 (2.30)</td>
<td>17.59 (2.16)</td>
<td>17.86 (2.92)</td>
<td>NS</td>
</tr>
<tr>
<td>Shearing force of loin (N)</td>
<td>46.74 (7.92)</td>
<td>47.56 (8.15)</td>
<td>45.22 (9.34)</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: The differences observed between the means are not significant; () standard deviation

**Table 3: Results of IDELE sensory analysis of loins by an expert panel in the three batches**

<table>
<thead>
<tr>
<th>NPPC marbling score</th>
<th>BATCH 1</th>
<th>BATCH 2</th>
<th>BATCH 3</th>
<th>Significant difference (Analysis of variance ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible IMF before cooking</td>
<td>1.30a</td>
<td>2.04b</td>
<td>2.50c</td>
<td>***</td>
</tr>
<tr>
<td>Lipid mouthfeel</td>
<td>1.99a</td>
<td>2.12b</td>
<td>2.51b</td>
<td>*</td>
</tr>
<tr>
<td>Juiciness</td>
<td>2.42</td>
<td>2.36</td>
<td>2.72</td>
<td>NS (10%)</td>
</tr>
<tr>
<td>Flavour intensity</td>
<td>3.08</td>
<td>3.16</td>
<td>3.30</td>
<td>NS</td>
</tr>
<tr>
<td>Tenderness</td>
<td>3.70</td>
<td>3.53</td>
<td>3.58</td>
<td>NS</td>
</tr>
</tbody>
</table>

***the differences between means are significant at an error rate of 0.1%; *1%; abc, means assigned different letters are significantly different at an error rate of 5%; NS: The differences observed between the means are not significant; () standard deviation
lipid mouthfeel (error rate < 1%). A tendency was also observed for juiciness (error rate < 10%), i.e. there was a tendency to find meats more juicy as the marbling score increased.

**NIR spectrum recordings to predict intramuscular fat (IMF) content**

The Labspec4 spectroscopy and surface probe were used to record visible and near infrared spectra on longissimus muscle at the level of the penultimate thoracic vertebra. The thickness of the cuts measured ranged from 1.5 cm to 2 cm and were presented systematically in the same side, laid out on a white cutting board.

Five spectra were successively recorded for each cut:
- One central (1): its statistical treatment was carried out individually for calibration purposes. This measurement performed at the core of the longissimus muscle raises obvious issues of representativity of intramuscular fat distribution over the whole muscle surface, the acquisition time being close to 1 s.
- Four contiguous (2, 3, 4, 5): these were averaged in order to obtain a spectrum with characteristics close to those obtained with a larger-diameter reflection probe (5 cm, acquisition time 4 s).

The NIRS spectra recorded were processed with MATLAB R2010a using toolbox SAISIR available at the website http://www.chimiometrie.fr/ (Prof. Douglas Rutledge).

The cross-validation procedure CROSSVALPLS was applied to manually determine the number of PLS factors in the prediction models for IMF contents.

The performance test on the equations obtained by external validation showed better results overall for four acquisitions, but with no real contrast with calibrations obtained from a single central acquisition (Table 4). The correlation IMF% / NIRS-predicted IMF% observed was greater (r = 0.61) and the prediction standard deviation was slightly lower (0.62), but this gain in precision remained low. Increasing the surface area measured is probably the way to go for further improvement of predictivity. One solution worth testing might be to use a larger-diameter probe, probably 50–55 mm.

The cross-validation procedure CROSSVALPLS was applied to manually determine the number of PLS factors in the prediction models for IMF contents.

**Conclusion**

This study reports a first finding: pork loins in France are only weakly marbled. According to the season, some 5–15% of loins score 3 or more on the US NPPC reference marbling scale (1–10). Fat, heavy male castrated pigs, with lower muscle content, present more marbled meats on average.

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**Table 4: Results for external validation performance in predicting IMF contents from prediction equations applied to a set of average spectra obtained by four acquisitions in longissimus muscle**

<table>
<thead>
<tr>
<th>Type of acquisition</th>
<th>Pre-processing of spectra</th>
<th>Number of PLS factors</th>
<th>Correlation predicted/observed</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus, average of four spectra (sites 2, 3, 4, 5)</td>
<td>-</td>
<td>9</td>
<td>0.61</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>SNV</td>
<td>4</td>
<td>0.51</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>1st order derivative</td>
<td>7</td>
<td>0.58</td>
<td>0.65</td>
</tr>
</tbody>
</table>

*visible and near-infrared spectroscopy = mean spectrum obtained by 4 acquisitions on longissimus muscle, wavelength range 350–1800 nm without pre-processing, 9 PLS factors

**Graph 8: Correlation between IMF contents obtained by the reference method (Folch) and the IMF contents predicted by visible and near-infrared spectroscopy* on an external validation set (n = 33) – r = 0.61
Chemical analysis reveals a statistically significantly higher intramuscular lipid content as the NPCC marbling score increases, thus validating this rating scale very widely used to satisfy market demand for marbled loins scoring 3–4 and more (Asian markets in general and in particular Japan and South Korea).

An IDELE expert panel confirmed the results of this marbling rating visually on fresh meat cuts. The NPPC scale is thus a first relatively efficacious method for sorting loins in the cutting room that can serve to differentiate products for the end consumer by visual sorting.

This study show some appreciable tendencies in taste improvement as loins go from scores of 1 and 2 to score 3 (lipid mouthfeel increases significantly, and also juiciness and flavour, though only tendentially).

As loins scoring 4 and more were not available, we were unable to demonstrate any further marked improvement in taste due to stronger marbling as appraised by the IDELE expert panel.

The use of a near-infrared probe developed by IFIP to sort the most strongly marbled loins in the cutting room seems promising provided the probe is adapted to increase the muscle surface area analysed. Marbling is not evenly distributed over the loin meat surface. The use of a probe of diameter 55 mm should improve the results obtained with this NIRS technology. The first results for France reported here are encouraging.

References


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How to cite

Improving the sensory quality of fresh pork meats by sorting based on variability in the intramuscular fat of loin