A METHODOLOGICAL APPROACH TO ASSESS THE INTERACTIONS BETWEEN ANIMAL PERFORMANCES, NUTRITIONAL VALUE AND SENSORY QUALITY OF MEAT

M.-P. Ellies-Oury[1,2,3], G. Cantalapiedra-Hijar[1,2], D. Durand[1,2], D. Gruffat[1,2], A. Listrat[1,2], D. Micol[1,2], I. Ortigues-Marty[1,2], J.-F. Hocquette[1,2], M. Chavent[4], J. Saracco[4] and B. Picard[1,2]

[1] INRA, UMR1213 Herbivores, 63122 Saint Genès Champanelle, France

[2] Clermont Université, VetAgro Sup, UMR1213 Herbivores, BP 10448, F-63000, Clermont-Ferrand, France

[3] Bordeaux Science Agro, 1 cours du Général de Gaulle, CS 40201, 33175 Gradignan, France

[4] Université de Bordeaux, UMR5251, INRIA, 33400 Talence France

Abstract – Animal performances (including feed efficiency), nutritional value and sensory quality of meat were characterized for young bulls of 3 breeds and 4 feeding regimes. Variables of each element of this triptych were arranged into homogeneous clusters in order to constitute different synthetic quantitative variable, which were further combined in Global Indexes. If the animal performances Global Index (GI) appears negatively correlated to the Sensory one, the Nutritional GI could be either positively or negatively correlated to the Sensory GI, depending on the way of expressing the fatty acid composition of meat. This method allows clearly discriminating breeds and feeding regimes in terms of the studied variables, and appears useful to contribute to pilot animal breeding for a better tradeoff management in the bovine sector.

Key Words – clustering of variables, meat quality traits, piloting animal breeding.

I. INTRODUCTION

The livestock sector is faced with an increasing demand by consumers for high-quality products, i.e. products that are safe, of good eating quality, nutritious and produced through sustainable farming practices [1] (Grunert, 2006). Nevertheless, beyond consumers, it is important to consider the whole meat supply chain, which includes all operators from farm to consumption. Thus, producers must be able to deliver and guarantee high-quality products to ensure consumers future purchase [2] (Grunert et al., 2004) and, at the same time, to provide a viable farm holding, and therefore an efficient production. The upstream of the livestock sector seeks to produce more efficient animals while producing meat with a controlled quality. The challenge is to conciliate the production of more efficient animals and of a controlled meat quality. To verify if it is possible, the present work intends to propose a methodological approach and to apply it to a set of experimental data 1) to clarify the interactions between animal efficiency / nutritional value and sensory quality of meat and 2) to assess how to control simultaneously all three elements of this triptych.

II. MATERIALS AND METHODS

The method was developed using data from the EU ProSafeBeef project. This study used 71 young bulls: Aberdeen Angus (AA, n=22), Blonde d'Aquitaine (BA, n=24) and Limousin (Lim, n=25). Animals were assigned during the finishing period (100 days before slaughter) to one of the four feeding regime: control group (Control; n=17), linseed (Lin; n=21), linseed and vitamin E (LinVitE; n=15), linseed and vitamin E and antioxidant (LinVitEAntio; n=18). There were slaughtered at about 17 months of age at a live weight around 665 kg. *Longissimus thoracis* (LT) samples were excised from the 6th rib 15 minutes after slaughter and sampled for later analysis. Weightings, measures, and analyses have enabled us to dispose of 76 variables characterizing the three elements of this triptych (Table 1).

First of all, it is necessary to point out the expectations when searching to improve animal performances and to master meat nutritional and sensorial quality. For example, as the diet of Western population is deficient in Ω3 fatty acids (FA), the challenge of increasing nutritional value could be based on an increase in the overall consumption of the health benefic FA (Ω3, C20:5n-3cis, C22:5n-3cis), as their dietary reference intakes (DRI) are usually not covered from our diet [3,4,5] (Astrog et al., 2004; Weill et al., 2002; Legrand et al., 2000). Nevertheless, increasing nutritional value could also be linked to a better balance between FA (increasing the ratio polyunsaturated/saturated fatty acids: PUFA/SFA, decreasing PUFAn-6/PUFAn-3 and C18:2n-6/C18:3n-3) concomitant to a decrease in the proportion of the less interesting FA (SFA, trans FA, …) [6] (Griel and Kris-Etherton, 2006).

Table 1 Variables available for each element of the triptych

Element of the triptych	Variables availables
Feed efficiency and Animal performances	Residual Feed Intake (RFI), RFI/Net energy intake, Feed Conversion Efficiency (FCE), Average Daily Gain (ADG), ADG/Net energy intake, Live Weight (LW), Metabolic Weight, Carcass Weight (CW), Carcass Yield, Meat Yield, Age, Amount of Fat, Muscles and Bone in the carcass, Carcass measurements (total lenght, thigh thickness, length shank-symphysis), Digestive and urinary tract content, Quantity of fat in the 5th quarter, Weight of the shinbones, Total composition of fat
Nutritional value	Amounts of Lipids, Fatty Acids (FA), Saturated FA (SFA), MonoUnsaturated FA (MUFA), PolyUnsaturated FA (PUFA), Conjugated Linoleic Acids (CLA), C16:0, C18:1 trans, PUFAn-6, PUFAn-3, C22:5n-3cis, C20:5n-3cis, %FA in total Lipids %MUFA, %SFA, %C16:0, %CLA, %PUFAn-3, %C18:1trans, %C20:5n-3cis, %C22:5n-3cis, %PUFAn-6, %PUFA in total FA Ratios C16:0/C18:0, PUFA/SFA, PUFAn-6/PUFAn-3, C18:2n-6/C18:3n-3 Content in Vitamins A and E, malondialdehyde (MDA), Carbonyl and Antioxidant status (AOS)
Sensory quality	Scores for Tenderness, Juiciness, Typical and Abnormal Flavour, Residue, Overall Liking, Warner-Bratler Shear Force, Activities of metabolic enzymes Isocitrate Dehydrogenase (ICDH), Lactate Dehydrogenase (LDH), Cyochrome-c Oxydase (COX), PhosphoFructoKinase (PFK), Citrate Synthase (CS), Proteins content, Proportion of each myosin isoform (% I, %IIA, %IIX+IIB), Total and Insoluble Collagen contents (TotalColl, InsolColl), Lipid content, ultimate pH, CIE L*a*b* color

These two situations might lead to a way of increasing nutritional value of meat, but come generally from such different types of meat (especially in terms of lipid content). Thus, depending on the definition given for each element of the triptych, different ways are possible (and sometimes antagonist) to achieve satisfactory compromises. To manage simultaneously all three elements of this triptych animal performances/nutritional value/ sensory quality, there was a need of a clear definition of the meaning of each of these three terms. Instead of using a participatory method requiring experts' advices, we used the R package ClustOfVar, specially developed to arrange variables into homogeneous clusters and to allow dimension reduction and variable selection [7] (Chavent et al., 2012).

For each of the three elements of the triptych, and in order to have an idea of the links between the quantitative variables that could characterize them, a hierarchy was constructed by a Principal Component Analysis (PCA). Then, for each cluster, Intermediate Scores (equivalent to the first principal component of PCA applied to all of the variables in the cluster) were calculated and used for recoding purpose. To characterize Intermediate Scores, the only variables having a square correlation with the central synthetic variable of the cluster (the central synthetic variable of a cluster is the first principal component of PCA applied to all the variables in the cluster) superior than 0.70 were used. Then, Global Indexes were established by combination of these Intermediate Scores in order to evaluate the interactions between animal performances / nutritional value and sensory quality of meat.

III. RESULTS AND DISCUSSION

For each element of the triptych, a PCA was carried out.

For animal performances parameters, the two first axes of the PCA explained 55 % of the variability (33% and 22%). The first axis was characterized by an opposition between CW, FCE, ADG and carcass amount of muscle on one hand and feed efficiency (negative RFI) on the other hand, whereas the second one opposed fat development (in the carcass and in the 5th quarter) and LW to carcass and muscle yields.

For sensory quality of meat, 47 % of the variation was explained by the two first axes. The first one (32%) opposed overall liking, lipid content and typical flavor to abnormal flavor, residue and proportion of glycolytic fibers (IIB+IIX). The second one (15%) was a color axis as it opposes L* (muscle lightness) to a* (muscle redness) and b* (muscle yellowness); (data not shown).

Concerning nutritional value of meat, the first two components in the PCA analysis explained around 66% of total FA variation (PC1 55%, PC2 11%). This PCA showed that, when lipid content increases, all of the FA content increases, but the proportion of healthy FA in total FA decreases (C22:5n-3, C20:3n-3, PUFA, PUFAn-6, PUFAn-3). Thus, increasing nutritional value in terms of DRI appeared negatively correlated with FA balance, justifying conducting two different clusters of nutritional variables.

For each element of the triptych, a cluster analysis was carried out on variables in order to constitute homogeneous clusters (*i.e.* groups of variables which are strongly related to each other and thus bring similar information), allowing to constitute Intermediate Scores. For example, when considering nutritional value of meat (either using composition of FA expressed in mg/100g of fresh meat, or proportion of each type FA), four Intermediate Scores were distinguished (Figure 1), in link with:

- higher contents/proportions of PUFA n-3 [IS.NV.1],
- PUFAn-6/n-3 ratios in favor of PUFAn-3 [IS.NV.2],
- lower total lipids, SFA and MUFA contents or proportions [IS.NV.3],
- lower lipid oxidation (less MDA, higher VitE content) [IS.NV.4].

The average of these four Intermediate Index (reclassified appropriately to be positively correlated to nutritional value according the literature) allowed to built a Global Nutritional Index.

In a consistent manner, a global sensory index was built using four Intermediate Scores linked to meat color and meat taste (higher sensory quality: decrease of L* and b* [IS.SQ.1]; increase of overall liking [IS.SQ.2]; increase of tenderness and decrease of residues [IS.SQ.3]; decrease of total and insoluble collagen [IS.SQ.4]). A global efficiency index was also built using four Intermediate Scores: 1) increasing FCE and LW [IS.AP.1], 2) increasing carcass and meat yields and muscle development [IS.AP.2], 3) increasing efficiency (decreasing RFI) [IS.AP.3] and 4) increasing carcass measurements [IS.AP.4].

Figure 1. CustOfVar dendrogram of nutritional parameters expressed in proportions of FA

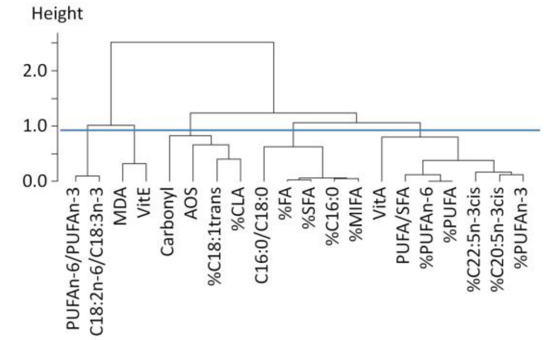
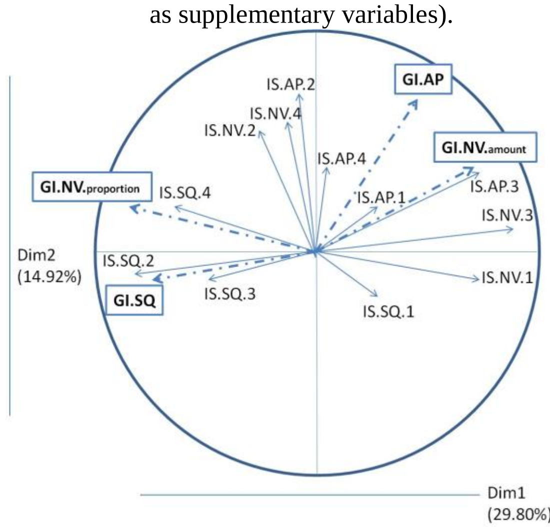


Figure 2. Plots of the first two principal component score vectors for intermediate scores (and global index as supplementary variables).



For this PCA, the Intermediate Score (IS) related to Nutritional Value (NV) were established using fatty acid composition expressed in amount (mg / 100 g of fresh meat). Two Global Index (GI) were calculated for NV: a GI calculated with FA composition expressed in amount (GI.NV.amount) and an another with FA composition expressed in proportion (GI.NV.proportion).

For each IS and GI, we indicated the element of the triptych (Animal Performances AP, Nutritional Value NV, Sensory Quality SQ) which is related to.

When considering together the three elements of the triptych, it appeared that the global index of animal performances is negatively correlated with the global index of sensory quality, which let us suppose that increasing the production efficiency of animals might be deleterious to quality of their meat (figure 2). It also appeared that nutritional value of meat could be either positively correlated or negatively correlated with sensory quality, depending on the way of expressing nutritional value (in mg/100g of fresh meat, or in % of total FA respectively). Thus, depending on the type of consumer and his expectations, it appears possible to increase both nutritional and sensory quality traits, or to find a compromise between these two aspects of meat quality.

Figure 3. Plot of the first two principal component score vectors showing individuals (breed being used as illustrative variable).

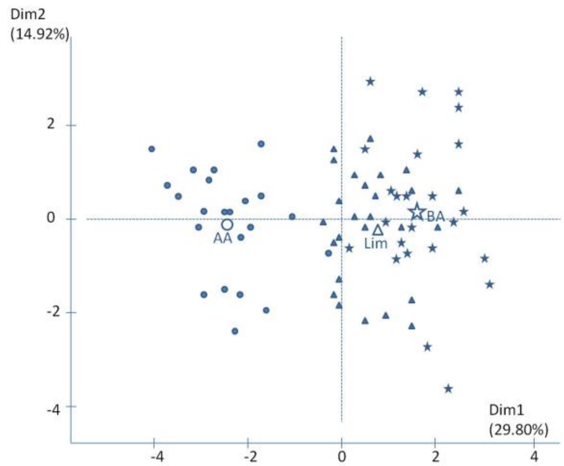
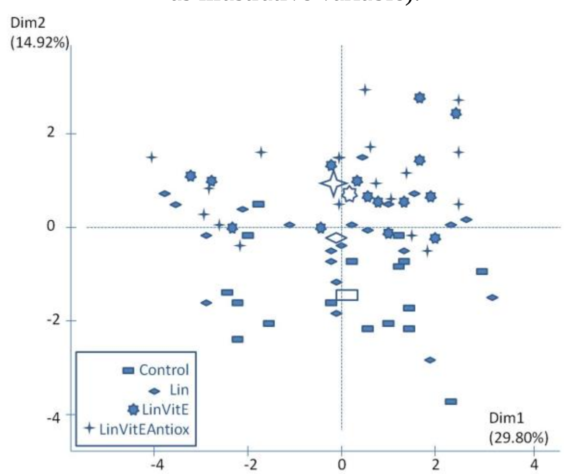


Figure 4. Plot of the first two principal component score vectors showing individuals (feeding regime being used as illustrative variable).



In each case, this method allowed to clearly distinguish the different types of animals in terms of breed (Figure 3) and feeding regime (Figure 4).

IV. CONCLUSION

The clustering of variables appears to be an interesting method to evaluate the interactions that exists between efficiency, nutritional and sensory quality. Over time, this approach could offer the possibility to provide an effective tool for integrating different concepts in order to pilot animals breeding as well as possible.

ACKNOWLEDGEMENTS

This work was part of the EU FP6 Integrated Project ProSafeBeef, contract no. FOODCT-2006-36241. Funding by the European Union is highly acknowledged with respect to animal production and laboratory analyses. We thank Pascal Faure (INRA UERT, Theix) for animal management and slaughter. We also thank all of the persons involved in this project for their assistance in data collection, the management and slaughtering of animals and muscle sampling. Finally, we thank Karine Méteau (INRA Le Magneraud), for sensory analysis.

REFERENCES

1. Grunert, K.G. (2006). Future trends and consumer lifestyles with regard to meat consumption. Meat Science, 74:149-160.
2. Grunert, K.G., Bredahl, L. & Brunso, K. (2004). Consumer perception of meat quality and implications for product development in the meat sector, a review. Meat Science, 66:259-272.
3. Astorg, P., Arnault, N., Czernichow, S., Noisette, N., Galan, P. & Hercberg, S. (2004). Dietary intakes and food sources of n-6 and n-3 PUFA in French adult men and women. Lipids, 39:527-535.
4. Weill, P., Schmitt, B., Chesneau, G., Norohanta, D., Safraou, F. & Legrand, P. (2002). Effects of introducing linseed in livestock diet on blood fatty acid composition of consumers of animal products. Ann Nutr Metab, 46:182-191.
5. Legrand, P., Bourre, J.M. & B. Descomps. (2000). Lipides. In A. Martin, Apports nutritionnels conseillés pour la population française (pp 63-82). Paris: Tec et Doc Lavoisier.
6. Griel, A.E. & Kris-Etherton, P.M. (2006). Beyond saturated fat: The importance of the dietary fatty acid profile on cardiovascular disease. Nutrition Reviews, 64(5):257-262.
7. Chavent, M., Kuentz-Simonet, V., Liquet, B. & Saracco, J. (2012). ClustOfVar : An Package for the clustering of variables. Journal of statistical Software, 50, 13.