Chemometrics and supervised learning for cows shear force prediction using the continuum data from farmgate to meat

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CHEMOMETRICS AND SUPERVISED LEARNING FOR COWS SHEAR FORCE PREDICTION USING THE CONTINUUM DATA FROM FARMGATE TO MEAT

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I. INTRODUCTION

Tenderness is one of the main drivers of beef palatability that consumers consider when they are making (re)purchasing decision [1]. The variability of tenderness affects negatively consumer satisfaction. Because beef meat is more expensive from other meats, beef industry seeks for new strategies that would provide products of consistent quality to meet consumer expectations. Thus, this study considers the continuum data, from farmgate to meat, i) to identify and understand the rearing factors and biochemical processes behind the variations in beef tenderness and ii) to provide decision tools that would help beef sector to improve the consistency of tenderness. Hence, partial least squares regression (PLS) and decision trees were applied in this work to achieve the fixed objectives on Protected Designation of Origin (PDO) Maine-Anjou cull cows.

II. MATERIALS AND METHODS

110 French PDO Maine-Anjou cows were used. The experimental design is described in details by Gagaoua *et al.* [2].The **rearing practices** of each animal were recorded by a survey, including *animal characteristics* [beef or dairy type; birth season; birth weight (kg); age of weaning (month); duration of weaning (week); age of first calving; number of calving; suckling value (0-10) and age at slaughter] and *finishing period* [part of hay, haylage and/or grass in the diet (%); amount of concentrate (daily (kg) and overall (%)); fattening duration (days) and physical activity (% days out)]. At slaughterhouse, **carcass characteristics** were recorded: hot carcass weight (kg), EUROP conformation score (1-15 scale), tenderness and color scores, ribeye weight (g), 6^{th} rib characterization by the weights of muscle and fat and their ratio. Samples from ***Longissimus thoracis* muscle** were excised 24 h *p-m* and characterized as detailed in Gagaoua *et al.* [2] for protein biomarkers including myosin heavy chains (%), oxidative and glycolytic enzyme activities (µmol min^{-1} g^{-1}), fiber area (µm^2) and insoluble and total collagen (µg OH-proline/mg DM). **Meat traits** were evaluated by fresh color (*L*a*b**) [3], ultimate pH and tenderness by Warner-Bratzler shear force (WBSF, N/cm^2) on beef cuts aged for 14 days. The 60 collected data at 4 levels of the continuum *i) farm* (q_X = 16), *ii) carcass* (q_X = 8), *iii) muscle* (q_X = 30) and *iv) meat* (q_X = 4/ q_Y = 1) were analyzed. First, the data were standardized using Proc Standard of SAS. Then, projections to latent structures by means of PLS was used to examine how the set of explanatory variables (q_X = 59) was related to WBSF (instrumental beef tenderness, q_Y). The filter method with the variable importance in the projection (VIP) was used for variable selection [4]. Thus, the variables with a VIP < 0.8 were all eliminated. Subsequently, the frequently used decision tree algorithms (C&RT, CHAID and QUEST) were performed to categorize the beef cuts according to their WBSF values using the retained variables in PLS. The best decision tree was obtained by Chi-squared Automatic Interaction Detection (CHAID) method.

III. RESULTS AND DISCUSSION

From the 59 X-variables included in the PLS model, 35 had a VIP < 0.80 and were eliminated. This improved the explained variation (R^2X: from 0.17 to 0.31) and the powerful of link with WBSF (R^2Y: from 0.37 to 0.64). The final model explained 75% of the variability of WBSF (Table 1). Among the 24 variables, 6 were from farmgate level, 4 from slaughterhouse level, 11 were protein biomarkers and 3 were meat traits. The decision tree (Figure 1) built using these variables allowed the identification of different groups of WBSF using 5 variables only. Three of them were the first drivers of the PLS model (highlighted in bold character in Table 1). The first splitter was total collagen that generated two groups. As expected, the 15 ribeye steaks with total collagen ≥ 3.6 µg OH-proline/mg had the highest WBSF values (tough meat). After that, the second group (n = 95) was clustered by µ-calpain at a threshold of 169 AU. The group on the right (n = 26) was then separated by ultimate pH at a threshold of 5.55 into medium (n = 14) and tender steaks (n = 12). The group on the left (n = 69) was separated by the age of weaning of the cows into a final tough group (WBSF ≥ 45.0, n = 18) and a medium group of 51 steaks, which were then categorized by fiber area into 30 tender and 21 tough steaks.

Table 1. WBSF PLS model showing the ranking of the 24 retained variables from the continuum data and their VIP values.

Continuum data	Rank	VIP
Farmgate level: rearing factors		
Age of weaning, month	**3**	**1.99**
Grass diet, %	10	1.31
Haylage diet, %	14	1.12
Birth month	15	1.11
Type (meat or dairy)	16	0.97
Activity at farm, %	24	0.84
Slaughterhouse level: carcass characteristics		
Conformation score, 1 – 15 scale	23	0.87
Ribeye weight, g	20	0.94
Color score, 1 – 5 sclae	5	1.80
Tenderness score, 1 – 5 scale	21	0.90
Muscle level: protein biomarkers		
Fiber area, µm²	**2**	**2.01**
µ-calpain, arbitrary units (AU)	**18**	**0.96**
m-calpain, AU	6	1.64
Isocitrate dehydrogenase (ICDH), µmol min^{-1} g^{-1}	7	1.57
Phosphoglucomutase 1 (PGM1), AU	11	1.27
Lactate dehydrogenase (LDH), µmol min^{-1} g^{-1}	22	0.89
Superoxide dismutase [Cu−Zn] (SOD1), AU	4	1.94
Protein deglycase (DJ1), AU	9	1.51
HSP70-8, AU	17	0.97
Total collagen, µg OH-proline/mg DM	**19**	**0.96**
Insoluble collagen, µg OH-proline/mg DM	13	1.18
Meat level: meat quality traits		
Ultimate pH	**1**	**3.29**
Redness (*a**)	8	1.53
Yellowness (*b**)	12	1.27

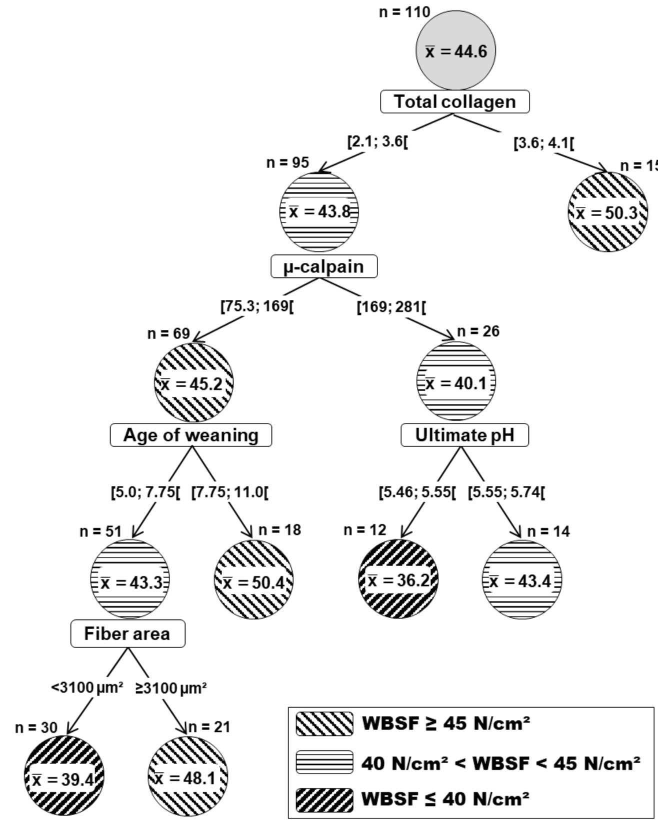

Figure 1. Best decision tree (CHAID method) built using the variables retained in Table 1 to predict WBSF values.

To sum up concerning the take home messages of the decision tree (Figure 1), a ribeye steak of the PDO Maine-Anjou was considered tender (lowest WBSF) if it matched the following rules:
i) **IF** (total collagen < 3.6 µg OH-proline/mg) **AND** (µ-calpain ≥ 169 AU) **AND** (ultimate pH < 5.55) **THEN** meat was very tender (mean WBSF values = 36.2 N/cm², n = 12); or
ii) **IF** (total collagen < 3.6 µg OH-proline/mg) **AND** (µ-calpain < 169 AU) **AND** (age of weaning < 7.75 months) **AND** (fiber area < 3100 µm²) **THEN** meat was tender (mean WBSF values = 39.4 N/cm², n = 30).
Furthermore, these findings highlighted the main biological mechanisms that are involved, mainly the structural properties of the muscle. We identified an interesting link within ultimate pH and proteolysis by the means of µ-calpain that are strongly involved in the determinism of tenderness of the investigated cows.

IV. CONCLUSION

These results highlighted the usefulness of the used set of methodologies to properly group steaks for their tenderness potential using variables of the continuum data from farmgate to meat. The proposed tool would be adopted for validation on other animal types or to be used by beef sector to categorize carcasses according to their tenderness potential. This would be beneficial at both the economic and consumer levels.

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