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Guaranteeing Canadian lamb meat quality using near infrared spectroscopy on intact rack

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Keywords:	classification, guaranteed, lamb, NIRS, quality

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Manuscripts

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19 **Abstract**

20 Lamb racks from commercial carcasses were scanned using near infrared spectroscopy (NIRS).
21 The predictions accuracies (R^2) for meat quality traits were assessed. Prediction accuracy ranged
22 between 0.40 and 0.94. When predicted values were used to classify meat based on quality, 88.7-
23 95.2% of samples were correctly classified as quality-guaranteed.

24 **Keywords:** classification; guaranteed; lamb; NIRS; quality

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26 Current classification systems for lambs in Canada focus only on carcass traits. With further
27 processing becoming more important for Canadian packers, rapid and non-destructive tools for
28 guaranteeing minimum quality standards for lamb meat could be adopted. Near infrared
29 spectroscopy (NIRS) has shown ability to predict lamb meat quality, especially chemical traits,
30 such as moisture and intramuscular fat content (Kamruzzaman et al., 2012). For most meat
31 quality attributes, NIRS predictability from whole carcasses or primal cuts is usually lower than
32 those from ground meat (Prieto et al., 2017). However, NIRS technology could be used for on-
33 line quality assurance purposes, even for those traits with limited prediction accuracy. The aim of
34 the present study was to evaluate the classification potential of portable NIRS on intact lamb
35 racks as a tool to guarantee the quality of lamb meat in the Canadian market. This technology
36 would allow packers to offer buyers meat with minimum quality attributes guaranteed, what
37 could be used to target niche markets with specific requirements and commercialized added-
38 value meat and meat products.

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MATERIAL AND METHODS

41 A total of 155 lamb carcasses, representative of the current variability in the Canadian lamb
42 industry (17-30 kg weight; 5-23 mm backfat thickness; 90-115 cm length), were selected from a
43 federally licensed plant (Innisfail, AB). At the Lacombe Research and Development Centre
44 (Lacombe, AB), intact lean (*longissimus thoracis*, LT) and backfat from lamb racks were
45 scanned at the level of the 13th rib using a portable LabSpec[®]4 Standard-Res spectrometer
46 (Analytical Spectral Device-ASD Inc., Boulder, CO, USA) from 350 to 2,500 nm (Vis-NIR
47 range) and a 20 mm ASD fibre-optic high intensity contact probe following 20 min bloom.

48 Spectral data were stored as the logarithm of the reciprocal of reflectance [$\log (1/R)$] in 1 nm
49 steps (2,151 data points).

50 Objective colour measurements from the posterior end of the LT were obtained in duplicate
51 using a Minolta Spectrophotometer Model CM 700D with SpectraMagic™ NX Lite Color Data
52 Software (CM-S100w Version 2; Minolta Canada Inc., Mississauga, ON, Canada) and averaged.

53 A chop removed from the posterior of the LT was ground and the intramuscular fat content was
54 analysed using NMR technology (SMART-Trac System, CEM Corporation Ltd., Matthews, NC,
55 USA). The adjacent chop was grilled to a final internal temperature of 71°C and two 1.9 cm
56 diameter cores were then used to determine peak shear force values (TA-Xt Plus Texture
57 Analyzer, Texture Technologies Corp., Scarsdale, NY, USA). Backfat free fatty acid methyl
58 esters were prepared and analyzed as described by Dugan et al. (2007).

59 All statistical analyses were conducted with SAS (v 9.4). Several mathematical transformations
60 were applied to NIR spectra prior to analysis, so the most accurate models could be developed.
61 Partial least squares regressions (PLSR) were run using the transformed and untransformed
62 spectra to determine their relationship with meat quality attributes and fatty acid groups. Internal
63 full leave-one-out cross-validations were performed on the models in order to avoid over-fitting
64 the PLSR equations. The coefficient of determination (R^2) from the resulting PLSR models was
65 used to determine the NIRS prediction accuracy. In order to develop a guaranteed quality system,
66 minimum quality thresholds were defined at the 20th percentile of the actual values for each
67 quality trait and fatty acid group (i.e. the value where 80% of samples would meet the minimum
68 quality threshold). For L^* , shear force, saturated fatty acids (SFA), and n-6 lower values
69 indicated higher quality, therefore thresholds were reversed so the 20th percentile was defined
70 according to the value where 80% of samples had lower values. The percent of NIRS predicted

71 values correctly classified within (non-minimum quality guaranteed) and outside the 20th
72 percentile (minimum quality guaranteed) were reported for all traits. Increasing the percentage of
73 correctly classified samples meeting the minimum quality threshold can be achieved by using
74 more stringent criteria to classify the predicted values. Therefore, NIRS predicted values were
75 reclassified and retested using two additional thresholds (25th and 30th percentile of actual
76 values).

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78 **RESULTS AND DISCUSSION**

79 Average values for quality attributes from lamb meat (Table 1) are within those previously
80 reported for commercial Canadian lamb (Pouliot et al., 2009). The NIRS prediction models for
81 quality attributes on intact lamb rack ranged in accuracy (R^2) between 0.40 for shear force and
82 0.94 for hue. These results are in agreement with those from other studies shown in the review
83 by Prieto et al. (2009), where high NIRS predictability was reported for meat chemical
84 composition and colour, but lower for tenderness in several species.

85 In commercial settings, being able to classify primals based on minimum quality requirements
86 might be more useful than predicting specific values. This approach may be especially useful for
87 attributes with lower R^2 , as it could allow accurate meat quality classifications based on any trait
88 using specific market requirements. When samples were classified according to the predicted
89 values using the 20th percentile quality threshold rank, 88.7-95.2% of samples were correctly
90 classified outside the 20th percentile (minimum quality guaranteed). The percentage of samples
91 correctly classified within the 20th percentile (non-minimum quality guaranteed) ranged between
92 54.8 and 80.6%. Although these thresholds were not based on industry standards, they allowed
93 for assessment of the classification protocols in the present study. In the case of shear force, with

94 a low accuracy for predicting actual values, the percentage of correctly classified samples was
95 still lower than for other quality traits (<90%). In order to successfully guarantee minimum
96 quality, the proportion of correctly identified samples meeting the minimum quality standards
97 needs to be high, with very few samples wrongly classified outside the 20th percentile. Increasing
98 the threshold rank for predicted values up to the 25th and 30th percentiles increased the
99 percentage of samples correctly classified outside the 20th percentile (91.8-98.1%). However,
100 correct classification within the 20th percentile decreased (46.8-61.7%). Therefore, as expected,
101 higher thresholds resulted in fewer samples wrongly classified outside the 20th percentile (high
102 quality) and more samples wrongly classified as within the 20th percentile (low quality).

103 Average fatty acid groups (Table 2) were in the range of those reported for commercial lamb
104 meat from different origins and countries (Juárez et al., 2008). NIRS prediction accuracies (R^2)
105 ranged between 0.57 for total monounsaturated (MUFA), and 0.94 for total polyunsaturated
106 (PUFA). In the review by Prieto et al. (2017), a wide range in R^2 for NIRS predictions of fatty
107 acid composition in lamb meat was also reported. The percentages of samples correctly classified
108 as meeting the guaranteed quality threshold (outside the 20th percentile) were 88.7% for n-6 and
109 95.2% for MUFA. The percentage of samples not meeting this threshold (within the 20th
110 percentile) ranged between 54.8 for n-6, and 80.6% for MUFA. As observed for meat quality
111 traits, higher thresholds (25th and 30th percentiles) resulted in higher percentages of samples
112 correctly classified as meeting the guaranteed quality threshold (outside the 20th percentile)
113 (90.7-95.2%) and lower percentages of samples correctly classified within the 20th percentile
114 (44.7-61.7%). This suggests that, in order to develop a system that can guarantee minimum
115 quality with a very high level of accuracy, a significant number of samples that do meet the
116 minimum quality threshold would be misclassified. This approach would be acceptable in cases

117 where a specific market demands a minimum quality at a premium price. This approach has been
118 used previously for meat quality assurance systems with other technologies, such as
119 hyperspectral imaging (Naganathan et al. 2015). In the case of Canadian lamb, fatty acid
120 composition is not a common trait for quality differentiation. However, the ability to classify
121 lamb meat with a guaranteed minimum content in fatty acid groups of interest would allow
122 added-value differentiation using current claim regulations (such as "source of n-3": 300 mg of
123 n-3 per serving; CFIA and Health Canada, 2009).

124 In the current study, NIRS has shown potential to guarantee minimum quality in traits such as
125 intramuscular fat, colour, tenderness and fatty acid composition. Results from the proposed
126 NIRS-based classification system show the possibility of manipulating thresholds for meat
127 quality traits and fat composition in Canadian lamb meat to achieve high levels of guaranteed
128 quality required by the industry. However, the thresholds used to classify lamb racks must be
129 balanced between client satisfaction and financial needs to maintain accuracy necessary to
130 guarantee quality but limit high quality samples that are incorrectly classified as not meeting the
131 threshold. Quality classification using NIRS could potentially be developed for other lamb
132 carcass primals; however, further research is required to establish scanning areas and suitable
133 quality traits.

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- 138 **CFIA and Health Canada. (2009).** Guide to Food Labelling and Advertising. Canadian Food
139 Inspection Agency, <http://www.inspection.gc.ca/english/fssa/labeti/guide/toce.shtml>. [Last
140 Accessed: July 11, 2017]
- 141 **Dugan, M.E.R., Kramer, J.K.G., Robertson, W.M., Meadus, W.J., Aldai, N., and Rolland,**
142 **D.C. (2007).** Comparing subcutaneous fat in beef and muskox with emphasis on trans-18:1 and
143 conjugated linoleic acids. *Lipids* 42, 509–518.
- 144 **Juárez, M., Horcada, A., Alcalde, M.J., Valera, M., Mullen, A.M., and Molina, A. (2008).**
145 Estimation of factors influencing fatty acid profiles in light lambs. *Meat Science*, 79, 203-210.
- 146 **Kamruzzaman, M., ElMasry, G., Sun, D.W., and Allen, P. (2012).** Non-destructive prediction
147 and visualization of chemical composition in lamb meat using NIR hyperspectral imaging and
148 multivariate regression. *Innovative Food Science & Emerging Technologies*, 16, 218–226.
- 149 **Naganathan, G.K., Cluff, K., Samal, A., Calkins, C.R., Jones, D.D., Lorenzen, C.L.,**
150 **Subbiah, J. (2015).** Hyperspectral imaging of ribeye muscle on hanging beef carcasses for
151 tenderness assessment. *Computers and Electronics in Agriculture*, 116, 55-64.
- 152 **Pouliot, E., Gariépy, C., Theriault, M., Avezard, C., Fortin, J. and Castonguay, F. W.**
153 **(2009).** Growth performance, carcass traits and meat quality of heavy lambs reared in a warm or
154 cold environment during winter. *Can. J. Anim. Sci.* 89: 229-239.
- 155 **Prieto, N., Roehé, R., Lavin, P., Batten, G. and Andrés, S. (2009).** Application of near
156 infrared reflectance spectroscopy to predict meat and meat products quality: A review. *Meat*
157 *Science*, 83, 175-186.

158 **Prieto, N., Pawluczyk, O., Dugan, M.E.R. Aalhus, J.L. (2017).** A review on the principles and
159 applications of near infrared spectroscopy to characterize meat, fat and meat products. Applied
160 Spectroscopy (In Press)

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