COMPOSITIONAL AND DIMENSIONAL FACTORS INFLUENCING PORK BELLY FIRMNESS

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Abstract –Belly firmness was measured using two methods (belly flop angle and subjective scoring) on left bellies from 198 pigs of three different genotypes, two sexes, two slaughter weights and fed three different diets. To model factors affecting pork belly firmness, contributions of dimensions (thickness, length, width), and composition (fatty acids, iodine value, proximate analysis) were assessed using multiple regression. The subjective belly score and belly flop angle were strongly and negatively correlated (r = -0.89). Regression analysis accounted for 77% of the variability in subjective belly firmness scoring, and 83% of the variability in belly flop angle measurement. The most important variables for both measurements of belly firmness were thickness and fatty acid composition. However, for subjective scoring, the composition of the subcutaneous fat was most important, followed by thickness, whereas for objective measurement (i.e. belly flop angle), thickness was followed by intermuscular fat composition. Belly length, weight and width influenced both methods of belly firmness measurement, but belly flop angle appeared to be the most influenced. After correcting flop angle using belly length, the effect of belly weight disappeared and effects of other variables were more similar to those observed for the subjective scoring, including the fatty acid composition of intramuscular fat.

Key Words –belly flop angle, iodine value, softness

I. INTRODUCTION

Pork belly softness has been reported as a major quality defect affecting packer and processor profitability and may subsequently discourage consumer decisions to repurchase [1,2]. Pork belly firmness is a multifactorial quality trait influenced by many interacting factors. Although commonly used by industry, iodine value (IV) has been reported to account for a relatively low proportion of the variability observed in pork belly firmness [3]. This may be due to the fact that it only relates to softness in fatty (i.e. adipose) tissue, while belly firmness may be determined by the combined effects of overlapping layers of lean and fat. Thus, more direct methods of measuring belly firmness have been developed, including visual appraisal [4], finger testing [5], compression and puncture measurements [6] and belly flop testing [7]. Belly flop tests measure the angle formed by the belly using either a suspended round bar [8] or a v-shaped smoke house stick [3,9]. Part of the variability measured by belly flop angle may be due to the influence of belly dimensions rather than actual firmness. Thus, the objective of the current study was to assess the relative contributions of dimensional and compositional factors on pork belly softness measurements.

II. MATERIALS AND METHODS

In order to obtain variability in belly firmness, a total of 198 pigs from three different genotypes [Duroc, Lacombe (Peak Swine Genetics) and Iberian (Semen Cardona) sires × Large White × Landrace F1 dams (Hypor Canada)] and two different sexes (barrow and gilt) were fed one of three diets [control or supplemented with either 5% canola or 5% flaxseed (supplied by O&T Farms Ltd.)] for three weeks with either 115 or 135 Kg slaughter weights [8]. After slaughter and chilling for 24 h (2°C), left pork bellies were removed following the Canadian Pork Buyer's Manual [10]. Belly bend was measured on skin-on, sheet-ribbed bellies draped over a round bar (8.3 cm Ø). The angle created under the bar by the belly was measured [8]. A 5-point visual and tactile response scale, based on commercial practices, was also used to categorize bellies into one of the following classes: (1) Firm fat, no finger depression, almost horizontal; (2) Firm fat, no finger depression, partly flabby; (3) Soft spongy fat, finger depression remains, flappy, roll over with resistance; (4) Soft spongy fat, finger depression remains, very flappy, roll over easily; (5) Soft spongy fat, finger depression remains, very flabby, roll over easily, oily. The following dimensional measurements were collected [7]: ribbed belly weight, length, and width at midpoint (Width1) and shoulder end (Width2) , fat firmness using durometer, thickness of *latissimus dorsi* (SLn); thickness of subcutaneous + intermuscular fat (SFt); *cutaneous trunci* at shoulder end (CuTr1) and mid-point, (CuTr2); near-midline belly side thickness either with (SThK) or without (SThK1) rib, thickness of intermuscular fat below the rib (Seam1) and in front of the rib (Seam2) and thickness of subcutaneous fat above (Subq1) and below *cutaneous trunci* (Subq 2).

Fat samples were taken from both the intermuscular and subcutaneous fat layers, about 15 cm from the cranial end of the belly. The *latissimus dorsi* was also sampled around the same area. Samples were analyzed separately according to the procedure described by Turner et al [11]. Iodine value was calculated using the equation: IV = [16:1]×0.95 + [18:1]×0.86 + [18:2]×1.732 + [18:3]×2.616 + [20:1]×0.785 + [22:1]×0.723 [12]. The whole belly was thereafter ground twice (3 mm plate, Butcher Boy Meat Grinder Model TCA22, Lasar Manufacturing Co., Los Angeles, CA, USA). Moisture content was determined as the weight lost during heating 100 g of ground tissue at 102 °C for 24 h and fat content was measured using petroleum ether extraction.

Pearson correlation coefficients among variables were calculated using the PROC CORR procedure of SAS V9.3. The stepwise regression (forward selection) procedure (PROC REG) was used to select the most precise and least bias models that can be applied appropriately for subsequent predictions ($P<0.05$). An additional regression analysis was developed using belly flop angle measurements corrected by belly length.

III. RESULTS AND DISCUSSION

The subjective belly score and the belly flop angle measurement were strongly and negatively correlated (r = -0.89; data not shown), indicating the potential for the belly flop angle method to measure pork belly softness. However, the regression analysis (Tables 1 and 2) showed differences in the influence of dimensional and compositional factors on each of these measurements of belly firmness. Other parameters negatively correlated with belly flop angle measurements included belly moisture and lean content, IV and linoleic acid content, PUFA and PUFA/SFA, n-6 and n-3 fatty acids (all three tissues), as well as belly width and the thickness of the *latissimus dorsi* muscle (r = 0.46-0.72; data not shown). Belly flop angle was positively correlated with belly total fat content, belly weight, fat firmness (from durometer), SFA (all three layers), fat layer thickness and overall belly thickness (r = 0.45-0.76; data not shown). Similar correlation values, but of opposite sign, were observed for the subjective belly score (data not shown). Belly softness defects are a result of industry efforts to satisfy consumers' demands for leaner meat product. A trend towards increased belly leanness would result in increased proportions of moisture and polyunsaturated fatty acid (PUFA) which may be characteristic of soft bellies [6].

Table 1. Stepwise regression values for subjective belly firmness (RMSE=0.43)

Variable	#	Partial R^2	Model R^2	C(p)
Subc. n-6%	1	0.549	0.549	166
Subq2	2	0.096	0.645	93.3
Interm. IV	3	0.032	0.677	70.5
Belly fat%	4	0.034	0.710	46.2
Lean n-6%	5	0.014	0.724	37.4
Width1	6	0.016	0.740	27.1
Weight	7	0.017	0.757	15.9
Length	8	0.011	0.768	9.00

It is unequivocal that changes in carcass fatty acid profile affect pork fat firmness [13,14]. However, this single factor did not totally explain the aggregated subjective perception of pork belly firmness. The large influence of the fatty acid composition of subcutaneous fat on the subjective scoring could be expected, as this measurement is based on the evaluation of three traits, two of them evaluated on the subcutaneous fat layer (Table 1).

The fatty acid composition of the intramuscular fat had a smaller influence on belly firmness subjective scores. However, the influence of seam fat fatty acid composition was larger on the global objective belly firmness (Table 2). Thus, although changes in the superficial fat layer may impact the subjective perception of belly firmness, any factors impacting the composition of seam fat could lead to larger effects on the actual pliability of pork bellies.

Although the thickness of the subcutaneous fat layer seemed to be the most influential dimensional variable, the thickness of muscles, such as *latissimus dorsi* and *cutaneous trunci*, also had an impact on belly firmness values. The large amount of variability in subjective and, especially, objective belly firmness measurements, explained by thickness variables indicates that thickness traits, either subcutaneous fat, total belly and/or lean layer thickness, could be considered, together with IV, for classification purposes.

Table 2. Stepwise regression values for belly flop angle measurements (RMSE=10.95)

Variable	#	Partial R^2	Model R^2	C(p)
Subq1	1	0.521	0.521	332
Interm. IV	2	0.137	0.658	186
Width1	3	0.035	0.692	150
Weight	4	0.051	0.743	96.5
Length	5	0.071	0.814	21.1
SLn	6	0.008	0.822	14.9
Subc. SFA%	7	0.005	0.827	11.2
CuTr2	8	0.003	0.830	9.97

Proximate composition did not seem to explain the variation in belly flop angle measurements in the present study (Table 2). However, subjective belly firmness scores were influenced by total fat content (Table 1). Jabaay et al. [15] and Schroder and Rust [16] suggested that substantial variation in moisture and protein content, as well as anterior to posterior separable lean content gradient, can contribute to the perception of belly softness.

Both subjective (Table 1) and objective (Table 2) belly firmness values were affected by belly width, length and weight. The influence of these variables was much larger for the belly flop angle measurements. However, while length was the trait with the smallest contribution to the model for subjective evaluation, it explained more variability in belly flop angle than did width or weight. During the subjective test, part of the procedure involves manipulating the belly and, therefore, changes in dimensional traits can somehow affect the evaluator's perception. In the case of the objective evaluation in the present study, the belly was suspended on a round bar by the middle line that goes from its medial to its lateral edges. Larger bellies will result in additional weight at the extremes of the sample, leading to an increase in bending and a decrease in the angle measured. In the case of bellies tested using v-shaped smoke house sticks, width would have the same effect, as samples are folded by the middle line that goes from their cranial to their caudal ends. Using this method, Whitney et al. [3], reported that belly width explained 33% of the variability in belly firmness, compared to the 14% explained by the IV. According to these results, correcting the belly flop angle measurements by the main dimensional variable affected by the position of the belly during the test could potentially improve the accuracy and repeatability of the method.

Table 3 shows the regression values after belly flop angle measurements were corrected by belly length. As previously observed, thickness and the IV from the intermuscular layer of fat explained most of the variability in the model. However, in this case, instead of Subq1, which is a fat thickness variable, the belly thickness value SThk1 was included in the model.

Table 3. Stepwise regression values for belly flop angle measurements corrected by belly length (RMSE=14.21)

Variable	#	Partial R^2	Model R^2	C(p)
SThk1	1	0.494	0.494	130.8
Interm. IV	2	0.113	0.607	61.2
Width1	3	0.066	0.673	21.6
Subq2	4	0.017	0.690	13.0
Lean n-6%	5	0.011	0.700	8.3
Lean n-6/n/3	6	0.004	0.705	7.6

Width was still the third variable, but belly weight was not included in the model. This supports the hypothesis that belly length would influence the results of the test by modifying the weight at the extremes of the sample and, therefore, the final angle of the belly. The fourth variable was another fat thickness trait, Subq2, followed by the percentages of total n-6 and polyunsaturated fatty acids (PUFA) in the lean layer. Intramuscular fat composition had not been selected in the original regression model for belly flop angle measurement but was included in the model for subjective evaluation.

IV. CONCLUSIONS

The present study suggests that thickness traits could be used, in combination with IV, to increase accuracy of belly firmness evaluation. Moreover, IV from tissue other than subcutaneous fat could also impact overall firmness. On the other hand, belly flop angle measurement has the potential to be used as an objective, rapid, inexpensive, non-destructive, on-line alternative for measuring firmness and for belly classification. However, belly length should be corrected for or standardized in order to avoid undesirable variations in angle measurements.

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