TOWARDS AN AUTOMATED PORK BELLY SYSTEM BASED ON DEGREE OF FIRMNESS

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I. INTRODUCTION

In Canada, since approximately 2010 the value of the pork belly has been increasing, becoming the most valuable cut in 2017 (Ontario Pork 2017). Soft bellies pose a problem for bacon processing, and commercial packers have begun to manually assess bellies (subjective scores following ribbing). Objective and automated assessment of pork belly firmness could improve the accuracy and speed of sorting.Objective measurements, such as iodine value, explain only a small percentage of the variability in belly softness (Whitney et al. 2003). Soladoye et al. (2017) reported a high correlation between belly flop testing and subjective belly softness scores. In the same study, the influence of dimensional factors, such as belly length, was identified. However, the original belly flop method is impractical for in-plant use.The aim of this project was to evaluate a prototype on-line sorting instrument, based on the belly flop test, for objective and automated classification of primal pork bellies according to firmness.

II. MATERIALS AND METHODS

Following Canadian commercial cutting specifications, rib-in bellies from a total of 402 hogs (~120 kg live weight) were collected at 24 h *post-mortem* (cooler temperature 2°C). In a room at ~ 7°C, belly angle was measured by placing bellies on a short, custom-constructed, manually-controlled moving conveyor, adjustable from 0° to 70°, with a movable nosebar (ø = 14 mm) positioned beyond the fore edge of the conveyor belt. Deep lean temperature of the *pectoralis profundi* was ~ 1.7°C. *Exp 1:* Paired bellies from the same carcass were held at 30°/50° or 30°/60°for120 s (skin down, caudal end foremost, at last exposed rib). *Exp 2:* At 30° the conveyor wasmanually advanced at ~ 6.8 cm/s until 24 cm of the caudal belly had passed the bar (Stop0s), allowing the belly to bend for ~ 20 s. Movies were captured for later measurements. Following bending, bellies were sheet ribbed and subjectively assessed by 2 experienced judges for floppiness; fat firmness, resistance to finger depression, and oiliness; and lean firmness. Proc MEANS (SAS V 9.4)was run for descriptive statistics, Proc CORR for Pearson correlation coefficients, and Proc STEPWISE to explain variance in belly angles obtained at different time points.

III. RESULTS AND DISCUSSION

From Exp 1 (n=52), it was confirmed that highest correlations between belly-drop angle and subjective scores were found for the 30° angle (r = 0.8-0.9).Mean distance from caudal end to last rib was 27.3 cm (SD = 1.9 cm). A point 24 cm from the caudal end of the belly was marked for the bend site, placing it just posterior to the last exposed rib on most bellies.

In Exp 2 the measured belly drop angles at time Stop 0s ranged between 179 and 81°. Subjective scores similarly showed a full range of floppiness, and a wide but not full range of other traits (Table 1). In general, strongest correlations were among scores related to fat or among fat measures, maybe because all hogs were mature with similar weights of lean meat, but different degrees of fatness. Correlations between Stop times and subjective scores were weakest with Stop-2s, strengthening to Stop0s, and changing little with increased Stop time.

Table 1.Descriptive statistics and correlation of subjective scores with belly drop angles at a 30° incline (n = 350)

Variable	Average±SD	Min-Max	Correlations				
			Stop -2s	Stop -1s	Stop0s	Stop5s	Stop10s
Floppiness	2.1±1.2	0-5	0.47**	0.75**	0.83**	0.84**	0.85**
Fat firmness	4.0±0.8	2-5	0.40**	0.55**	0.57**	0.58**	0.58**
Oiliness	4.4±0.6	2.5-5	0.29**	0.55**	0.60**	0.60**	0.60**
Finger depression	3.9±0.9	1-5	0.35**	0.50**	0.54**	0.54**	0.55**
Lean firmness	3.1±0.5	1.5-4.5	0.25**	0.33**	0.33**	0.34**	0.35**

Stop 0s = drop angle at time conveyor stopped moving, Stop -1s & -2s = drop angle 1 and 2 seconds before conveyor stopped moving, Stop 5s, & 10s = drop angle 5 and 10 seconds after conveyor stopped moving

The model R^2 for each time point (Table 2) also shows small improvement beyond Stop0s. Overall, the drop angle at Stop -2s and -1s could be considered unreliable simply because too little of the caudal belly had passed the nosebar. With the premium on time in a production situation, likelythe value of the degree of improvement in bend prediction with longer stopping times would be outstripped by the cost of the time to perform them. Thus, Stop 0s is left as the earliest reliable time to measure the drop angle of a belly moving at the speed used in this study. Additionally, as the Stop0s measurement was taken at the instant belt movement ceased, in practice halting the belt may not be needed if the angle at the 24 cm point can still be measured.

Table 2. Stepwise regressions for prediction of belly degree of bend using subjective evaluations (n=351)

Dependent	# Traits	R^2	C_p
Stop -2s	2	0.243	4.964
Stop -1s	5	0.602	6.000
Stop 0s	5	0.717	6.000
Stop 5s	5	0.740	6.000
Stop 10s	4	0.743	7.797

Stop 0s = drop angle at time conveyor stopped moving, Stop -1s & -2s = drop angle 1 and 2 seconds before conveyor stopped moving, Stop 5s, & 10s = drop angle 5 and 10 seconds after conveyor stopped moving

Automation of this concept could include technologies such as machine vision or electronic eyes to aid in categorization based on the drop angle. However, based on observations of the prototype, using the normal behavior of the bellies in response to gravity could be a simpler solution. Furthermore, because of the range of drop angles, a slow-speed, and non-stop, horizontal conveyor could be as effective as the original prototype (concept being currently tested). As time and volume are important factors in production, an option could be to sort in stages using a combination of conveyor belts and speeds. Finally, carcass flank fold was identified as a potential source of error, and belly flattening as an alternative to address this issue.

IV. CONCLUSION

The results of this project suggest measuring bend angle of pork belly primals could be feasibly utilized as an automatedmethod for sorting bellies based on firmness. A set of subjective standards was also developed for evaluating belly fat, lean and overall firmness.

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