DIMENSIONAL CONSIDERATIONS OF TEST PIECES FOR BELLY-FLOP ANGLE TESTS OF FAT SOFTNESS

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Abstract-The belly-flop angle test is a simple measure for determining the softness of fat in pork bellies. This study analyses the belly-flop angle test from simple beam-bending theory and highlights the relationships between angular deflection, test piece dimensions, stiffness and intrinsic characteristics of the sample, based on simple engineering terms. Results indicate a positive correlation between belly-flop angle versus belly thickness and fat melting point. Belly thickness was also related to melting point in our test specimens. By correcting the results for specimen dimensions, a more accurate relationship between belly-flop angle and fat stiffness can be obtained.

Key Words –bellies, melting point, thickness.

I. INTRODUCTION

The softness of pork belly fat is a factor in ease of bacon cutting. Diverse measurements such as melting point, refractive index, slip point, and subjective firmness are used to estimate this softness, In Industry the belly firmness scale is used and belly flop measurements are indicators of The belly-flop angle test is a simple test that aims to quantify the softness of fat pork bellies, as a less firm belly, with a higher proportion of unsaturated fat, tnds to sag more.[1]. Soladoye et al. [2] show that this test correlates well with trained subjective assessment of softness (as judged by thumb indentation) and also find that the belly-flop angle scales with the length of the test piece.

From a materials science point of view, the deflections in a belly suspended at its mid-point can be described by the simple linear elastic beam-bending theory found in many standard engineering textbooks, for example Gere and Timoshenko [3]. The angle α, as defined by Apple et al. [1] as the angle in degrees subtended between the two ends of the sagging belly, can be approximated from beam bending theory by the following equation:

$$\alpha = 180 - 4\left({WL^2}/{Ebt^3}\right) = 180 - 4({\rho L^3}/{Et^2})$$

Where W= weight of the sample, b=width, t=thickness, ρ =density and E= modulus of elasticity, or stiffness. The assumptions behind standard beam-bending theory is that the material that makes up the beam is uniform and linearly-elastic, and that the cross-section of the beam has the same shape and size throughout its length. Although theoretical analyses do exist for composite beams made of two or more elastic materials and for various types of inelastic bending of uniform, these formulations become cumbersome and do not detract from message the belly-flop angle is likely to be dependent on length, width and especially thickness of sample being measured. The angle will, of course, depend on the temperature of measurement,

The purpose of this study is to use the theoretical framework of beam-bending theory to highlight the characteristics of the specimen that influence the belly-flop angle test and in particular the expected effects of specimen length, width and depth (thickness) on the angular deflection seen. The results are also calibrated against the results from standard fat melting point tests. The aim is to create a greater understanding of the variables affecting this simple test.

II. MATERIALS AND METHODS

Crossbred castrated male (n = 20) pigs ,all from the same local producer (in Tandil, Buenos Aires, Argentina), were used. All animals were allowed *ad libitum* access to water and feed in pens and were grown to a live weight of 91.05 ± 7.78 kg. All pigs were transported together to a commercial pork slaughterhouse and slaughtered in accordance with Argentinian regulations. After 48 h in the chill room, bellies from the left side of each carcass were trimmed out manually. The length and width of each belly were measured with a steel rule and the thickness measured by vernier calipers. The pH of the inner fat layer was measured using a pH meter (Testo 250, Germany) in each belly . A digital camera (Nikon Coolpix P610, 16 megapixel with 4.3-258 mm lens; Japan) was held at a fixed distance of 1 m horizontally from a steel cantilevered pole of 3.5 cm diameter and the lens zoom setting fixed. The belly was placed skin side down over the cantilever and photographed. Kinovea software (Kinovea 0.8.15 Public License version 2. http://www.kinovea.org/) was used to quantify the angle between the two sagging ends of the belly shown in each photograph (figure 1). Specimen dimension measurement and the photographs of the belly-flop angle were all conducted in a chill room set to 7-8°C. Sub-samples of each belly were vacuum-packaged, boxed, and transported under refrigeration to the laboratory where melting point and specific weight were assayed.

Figure 1- Pork Belly-flop angle test analysis.

Melting point: The melting point (MP) of the belly fat was analysed by the open capillary method. Capillaries were immersed in a thermostat-controlled bath with temperature increasing at a rate of 1ºC per minute. began rising in the capillary and the temperature at which the solid in the capillary tube melts was noted. Three capillaries from each belly sample was assayed and their average taken as the melting temperature.

Specific weight: Cubes of approximately 1cm^3 were cut from each belly and measured accurately. The weight (m_i) and tissue volume (V_i) of three-cubes of each sample were determined. The volumes of the cubes were measured by liquid water displacement in a calibrated measuring glass cylinder. The ratio of bellies tissue weights (m_i) and volume (V_i) were defined as specific weigh according to Archimedes' principle.

Statistical analysis

The results were reported as the average and standard deviation of 20 animals. Simple correlations among variables were calculated and regressions were evaluated using Microsoft Office Excel 2010.

III. RESULTS AND DISCUSSION

The sample temperature at time of dimensional analysis and photography was 7.95±0.19 °C. The cut bellies were quite uniform in size with an average length and width of 48.4±4.5 and 26.2±1.9 cm (mean±standard deviation), respectively. The pH (6.84±0.22) and tissue specific weight (0.96±0.03 g/cm^3) were also relatively uniform across all samples.

The belly-flop angle showed differences between speciemens and had a positive relation with sample thickness (mm) (**Figure 2a)**, as expected, due to the thickness contributing significantly to the resistance to bending (via the second moment of inertia of the specimen [3]. The belly-flop angle showed an interesting and positive relation to the melting point of the belly fay (MP). The angle increased (i.e. the belly was less floppy) as MP increased, as shown in **Figure 2b.** The correlation (R^2) for angle *vs* thickness and MP were and, respectively.

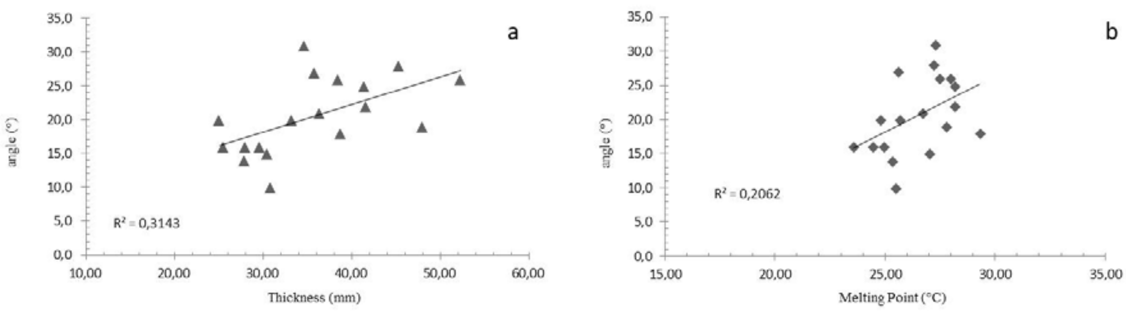

Figure 2- Relation belly-flop angle *vs* thickness **(a)** and angle *vs* Melting point **(b)**. Linear model.

Even though the the animals studied were all from the same feedlot and slaughtered on the same day, belly-flop angles between 24 and 49º were observed. With an average angle 35.6° and standard deviation of 8.1°, this corresponded a 23% of coefficient of variation (CV). Soladoye et. al [1] obtained a 50% CV in angle measurement in their population of 198 animals. Our results suggest that a reduced CV could be achieved id specimen dimensions were taken into account and show that linear and positive relationship between the MP and thickness of the samples exists (**Figure 3**). The different samples analysed showed a variety of the belly layers, with an observable variation of subcutaneous fat thickness, despite the fact that variations in density were minimal.

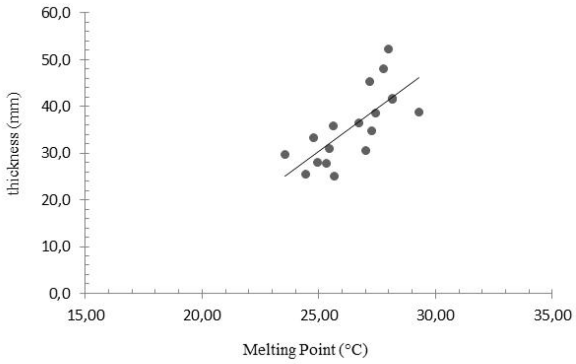

Figure 3- Belly thickness *vs* Melting Point (linear model).

This study shows that simple measurements of length, width and especially thickness of the bellies can be used to increase the accuracy of this simple test to predict the stiffness of belly fat. These additional measurements do not detract from the practical usefulness of this test suitable for commercial meat plants. While there is clear evidence that the test distinguishes between belly fats of different melting points, further studies are needed to relate the results to fatty acid composition.

IV. CONCLUSION

Results confirm that the dependence of belly-flop angle on the length, width and thickness of pork bellies is in line with the predictions from simple beam-bending theory, despite the approximations in such a model. It is recommended that length, width and thickness dimensions are taken into account in order to make the belly-flop angle measurements more consistent and more representative of the stiffness of the material (mainly fat) that makes up the belly. It is also important to note that the stiffness of the fat in pork bellies is strongly dependent on temperature, and so control of specimen temperature is essential when comparing results.

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