MethodsX 12 (2024) 102577

Contents lists available at ScienceDirect

MethodsX

journal homepage: www.elsevier.com/locate/methodsx

A new manual method for pork belly firmness measurement

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ARTICLE INFO

Method name:
Rapid belly firmness measurement

Keywords:
Bacon
Bend
Iodine value
Softness

ABSTRACT

A new objective and standardized method for early determination of firmness of the intact pork belly in a research environment is described, and compared to the existing bar-bend method. The belly characteristics that contribute to the outcome of each method, and the relationship between the two methods are identified.

- Original method requires a ribbed pork belly, and several minutes relaxation time.
- New method provides an immediate measurement on an intact belly.
- Advantages include early, rather than late, application in the fabrication process; rapid measurement; standardization; measurements minimally affected by animal length or belly length.

Specifications table

Subject area:	Food Science
More specific subject area:	Pork quality
Name of your method:	Rapid belly firmness measurement
Name and reference of original method:	• Most commonly known as 'bar bend'. • First known reporting in scientific literature: Thiel-Cooper, R. L., Parrish Jr., F. C., Sparks, J. C., Wiegand, B. R., & Ewan, R. C. (2001) Conjugated linoleic acid changes swine performance and carcass composition. Journal of Animal Science, 79:1821–1828.
Resource availability:	n/a

Method details

The firmness of pork bellies directly relates to their overall quality, the markets they can be directed to, the products they can be used for, and their economic value. Measuring pork belly firmness may be subjective or objective. Subjectively, the firmness of ribbed pork bellies (i.e. ribs removed) can be evaluated by how easily they fold or roll, and how the tissues feel when handled. Numerical evaluation scales may be composed of compound scores which combine several physical characteristics which are usually positively correlated [1], of a series of single-characteristic scores [2], or of an estimate of distance moved when folded (Harsh et al. [3]). Objectively, the original Bar Bend method was pioneered at Oscar Mayer [4] as early as the 1970s. In this method, generally a ribbed belly is placed on a horizontal bar, permitted to fully relax for a period of time, then either the angle created at the bend point, or the distance between the two drooping ends, is measured (see Fig. 1).

This method has been described as suitable for firmness categorization [4], and since approximately 2001 has been reported in scientific literature as an objective research measure of belly firmness, although with considerable variation in application. These

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https://doi.org/10.1016/j.mex.2024.102577
Received 14 September 2023; Accepted 18 January 2024
Available online 22 January 2024
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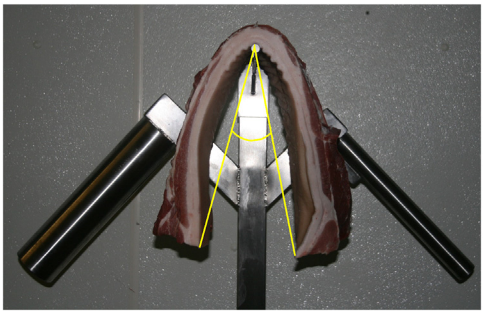

Fig. 1. Bar Bend angle measurement on stationary ribbed belly following 2 min resting time. 10 mm ø bar installed and larger diameter bars in storage positions.

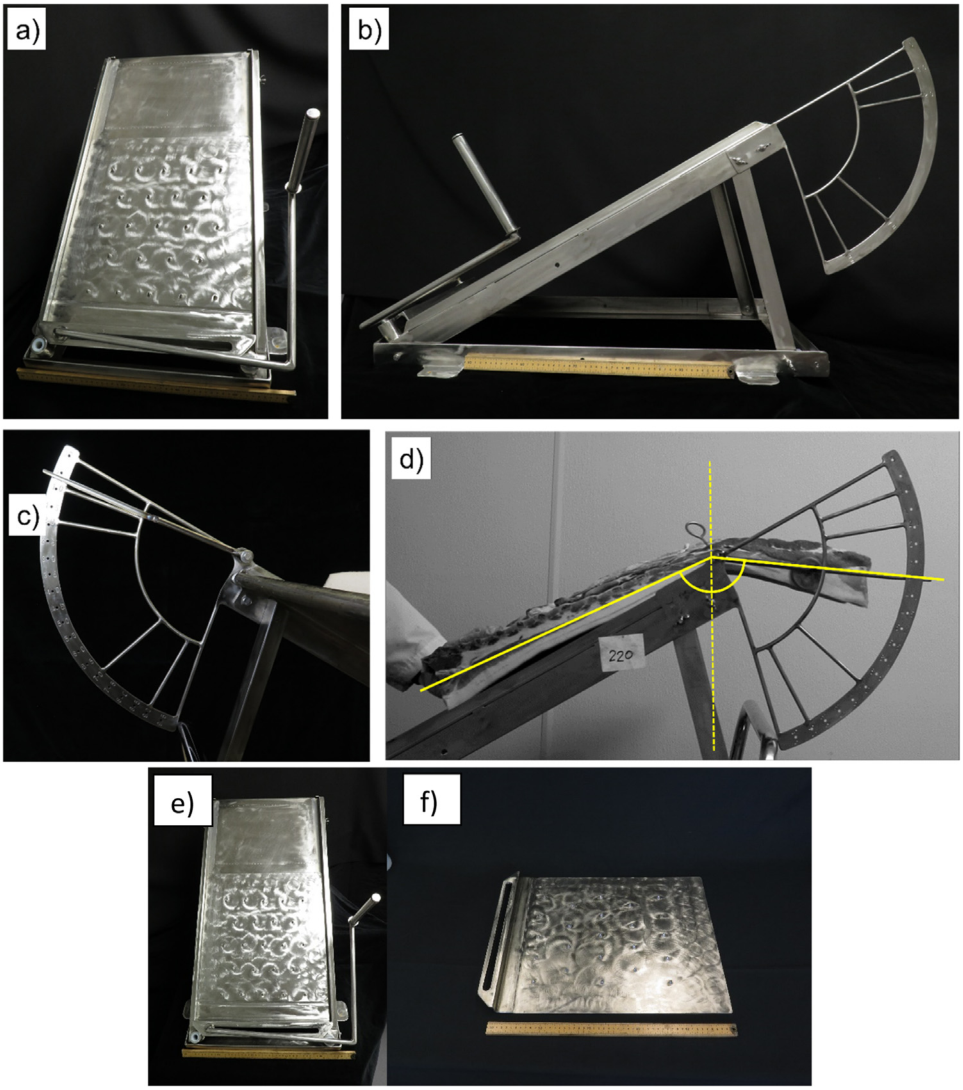

Fig. 2. Belly Bender Version 2 (BB.V2); a-c) equipment views, d) belly angle measurement on a moving belly; e-k) detailed measurements of individual components.

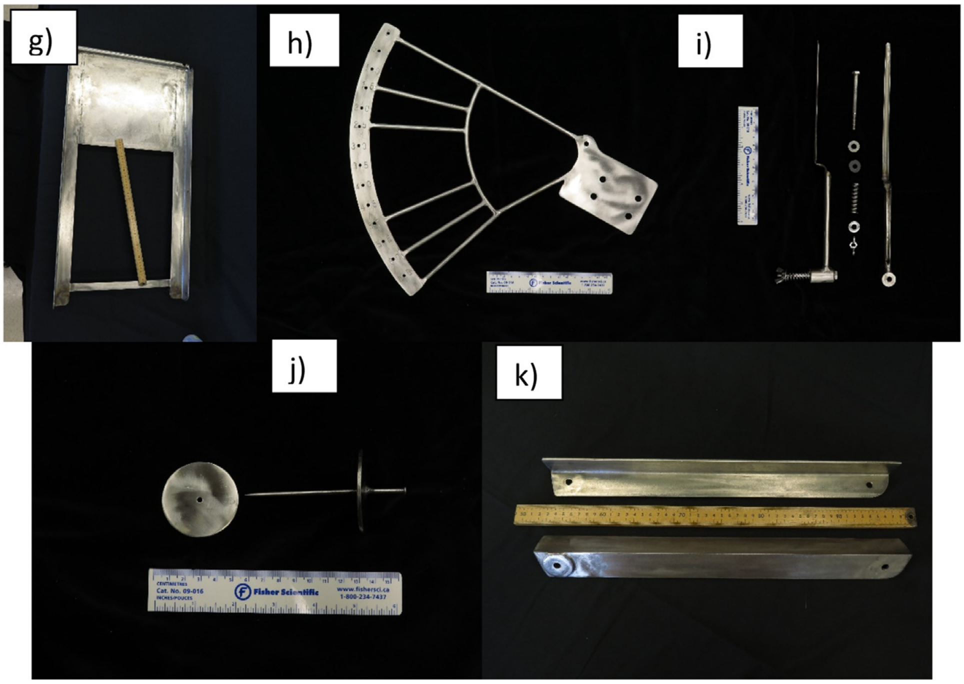

Fig. 2. Continued

include a wide range in relaxation times (2 min: [1,5]; 5 min: [6]), and bar diameters (1 cm: [7,8]; 1.9 cm: [9,10]; 5 cm: [5]; 7.6 cm: [11]; 8.3 cm: [1]). While most work has used cylindrical bars, use of smoke sticks has also been reported [12]. Smoke sticks are generally angular lengths of metal with a cross section of approximately 2.5 cm. Soladoye et al. [1] observed that the method would be in need of modification if incorporation on a production line was desired. Such a modification was explored by Uttaro et al. [2] with non-portable equipment (Belly Bender version 1; BB.V1) on which the amount of bending incurred by a primal belly when manually advanced over a narrow edge was assessed in relation to subjective firmness evaluations. The outcome showed strong support for instantaneous belly firmness categorization and led to a simple gravity-based automated sorting system tested at the rate of 22 m/min to classify very firm, very soft, and intermediately firm bellies [13].

A portable manually operated version of the BB.V1 was created for standardized measurement (Belly Bender version 2; BB.V2) rather than for categorization, and the method which employs it is being described here. See Fig. 2 for views of, and angle measurement with, the BB.V2. The aim of both the Bar Bend and BB.V1 & 2 methods is similar, although bend site, state of belly deconstruction, and relaxation times are quite different. This method could be of interest for both quality control teams in packing plants and researchers. The rapid testing offered by the new BB.V2, plus its portability, make it ideal for the evaluation of large numbers of bellies under different conditions.

Equipment description

A piece of stainless steel equipment, called the BB.V2 was developed by the authors and R.A.M. Welding (Stettler, AB, Canada) to execute the method. The equipment consists of a lever-actuated sled moving along a ramp that can be positioned at either 0° or 30° The end of the ramp (nosebar) is 19 mm ø and has an optional angle gauge and measuring arm attached to it. The equipment must be clamped to the work surface, and can be operated from either side by changing the lever. Ultra-high molecular weight (UHMW) tape between moving parts aids in smooth operation, and metal stops at the end of the ramp halt movement of the sled to allow the operator to move the sled forward at a steady pace without slowing down as the end of the test is reached. The cost of developing the equipment in Alberta (Canada) ranged between CAD $5000 and CAD $10,000. This could differ depending on the price of materials and manpower at different locations. There are no additional costs associated to using the instrument.

Belly preparation

Pork bellies must be prepared in a consistent fashion. The reported method was developed using pork bellies removed from the left side of 413 carcasses at 0 to 2.9 °C, 24 h post-mortem, and handled in such a way as to avoid flexing them prior to the test. Cutting specification for these bellies followed standard Canadian cutting lines [14] in which the shoulder was removed between the 2nd & 3rd ribs with a cut perpendicular to the longitudinal axis of the carcass, and the ham removed with a cut placed approximately 5 cm cranially to the aitch bone, with the ventral end of the cut angled cranially at approximately 65° to the longitudinal axis of the back

Fig. 3. Pin placement in a long bely using a 10 cm ruler at the caudal end for BB.V2 testing.

(i.e., perpendicular to the longest axis of the back leg). This removal point results in a long belly/short ham. The loin was removed following a line running from just ventral to the thoracic vertebra at the anterior end, to immediately ventral to the *psoas major* at the posterior end. All ribs and cartilage remained in the belly, constituting the primal belly. This is the form of the belly when measured with the BB.V2. For the Bar Bend method, ribs and cartilage must be removed, which is usually done as a single sheet. Cutting into the belly disrupts tissues to differing extents depending on the ribbing technique used, and allows more flexibility in the ribbed belly than in the unribbed belly.

The bending point for measurement with the BB.V2 is at, or just caudal to, the last remaining rib in the belly. The location has been standardized at 24 cm from the caudal end for the long belly/short ham generally cut for the North American market, and at 16 cm for the short belly/long ham which results when the back leg has been removed between the last and second-last lumbar vertebra for some markets. The bending point for the Bar Bend is the same as the balancing point of the belly, which is near its midpoint.

Test execution

The basic concept is to advance the belly, skin-down and caudal end foremost, at a steady rate over a narrow diameter edge, for a predetermined distance, then measure the angle created at the instant the target bending site reaches the edge.

On the BB.V2, a belly is placed as described, with the end of the belly positioned at the nosebar, and the long axis of the belly aligned with the long axis of the equipment. Then one steadying hand is placed on the cranial end to keep the belly from sliding backwards, while the other smoothly pulls the handle at a predefined and steady rate until the bending point has clearly passed the end of the ramp. The hand on the belly continues with the belly, up the ramp.

Bend measurement

There are two options for measurement. If the angle gauge and measuring arm was not used, before the test, a pin must be placed upright in the belly at the 24 cm (or 16 cm) bending point, and a video clip of the test captured. Then the frame in which the pin became positioned directly over the nosebar must be isolated, and the angle created by the bending belly, measured. The center of the belly thickness on each side of the bend site is used to guide placement of angle arms. On some bellies this results in the apex of the angle being located above the belly. If the angle gauge and measuring arm have been used, the angle of bending can be read directly from the angle gauge. The measuring arm consists of a tube with a specific length slit. At one end of the slit goes the head of a pin that has been placed horizontally either 10 cm (long bellies) or 4 cm (short bellies) from the caudal end of the belly, which results in a small portion of the caudal belly hanging over the nosebar (Fig. 3). As the belly is advanced, the measuring arm follows the movement of the pin. When the pin exits, the measuring arm remains in place even though the belly continues to move. The amount of bending may be read off the angle gauge which has been marked in 5° increments.

Operational considerations

While performing the test the two most important points are belly temperature and test speed. Temperature can have a large effect on overall belly firmness, with warmer temperatures decreasing firmness. Therefore, as with other belly firmness or flexibility tests, the temperature should be kept within a narrow range. Ideally, 1 °C variability within the larger range of 0–2.5 °C. The slower the test speed the longer the belly has to bend as it passes the nosebar. On the other hand, extremely fast speeds compound short deformation times with accumulated momentum, so distinguishing between different firmnesses is more difficult. It was found that when not using the measuring arm, a test duration of approximately 4 s was suitable. This could be reduced to 3 s when the measuring arm is used, as the belly starts further up the ramp.

Test each belly only once, because unless they are very firm or very soft, bellies bend further with closely-spaced sequential bendings. This is the reason for careful pre-test handling which avoids flexing. If something has gone wrong and a second test is needed, set the belly aside, skin side down and flat, for half an hour or more in a place where it will stay within the temperature range for the study, then redo the test.

Very lean bellies have a tendency to resist moving up the ramp. This can be remedied by spraying or wiping the ramp with water.

Since it is the rib-free portion of the caudal end of the belly which is being tested, carcass cutting lines which produce a long shoulder, and so a short belly at the anterior end, will not affect measurements. Likewise, since the portion of the belly passing

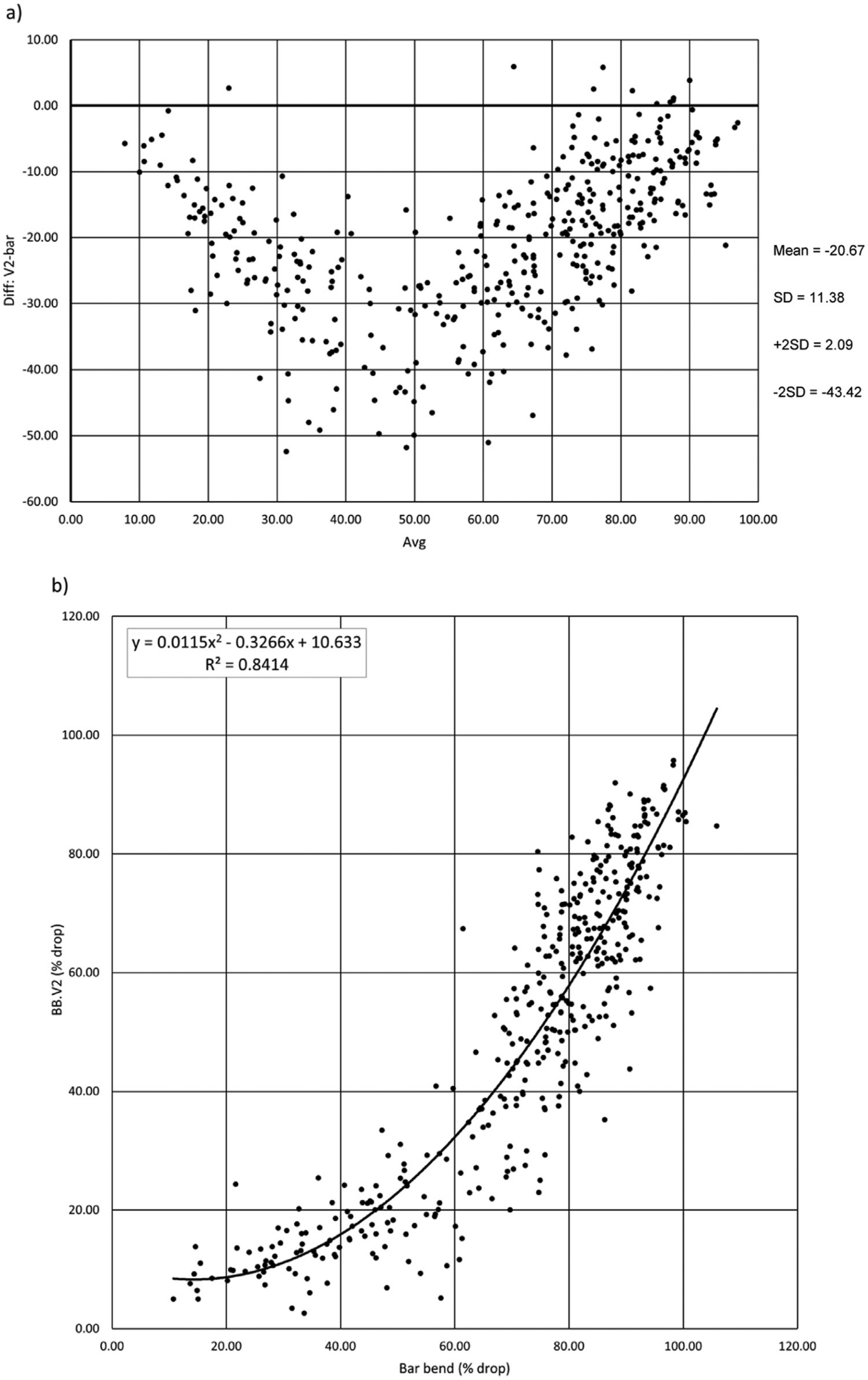

Fig. 4. Comparison of methods, using% drop (a) average vs difference between new method and original method, (b) direct quadratic relationship.

the nosebar is standardized, variations in animal length and carcass weight (both, within reason) will have little impact on the measurements.

Although the method was developed specifically for bellies that have been freshly removed from the carcass so that there would be minimal interference from fabrication steps, it may also be used for bellies which have been flattened and/or ribbed (sheet or singly) and/or skinned. However, the degree of bending can be expected to be greater with each fabrication step, and differentiation between firmnesses may be poorer.

Unlike the original Bar Bend method, the new method is standardized; faster; applied before the primal can be affected by handling associated with primal fabrication; not affected by length of the belly; and very firm bellies do not require monitoring to ensure they remain balanced on a bar. However, since the measurement is taken very early in the bending process, belly firmnesses may not be distinguished as clearly as they may be after the prolonged relaxation employed by the original method, provided carefully managed and handled bellies have been used for the latter.

Method validation

Bellies were measured with both the new and original methods, and angle measurements converted to% drop before comparison. This was because with the Bar Bend method both ends of the belly move and, given the 10 mm diameter of the bar used, allowed a maximum movement of 170° (85° by each end), while with the BB.V2 raised to 30°, only one end could move, to a maximum of 120° Fig. 4a uses average vs difference [15] to compare belly bending behaviour with the two methods wherein the amount of bend from very firm (left) and very soft (right bellies) was somewhat similar for both methods, while for all firmnesses in between, the amount of bend was always considerably greater with the original method. This could be expected, as extreme bellies (very firm and very soft) seem to respond similarly to the effect of gravity in both methods (maintaining shape and fully bending, respectively), while intermediate bellies may show different behaviours under different conditions, especially testing time. Intermediate bellies will continue to bend over time in the traditional method due to the continuous effect of gravity. Fig. 4b shows the direct, quadratic, and strong relationship between measurements from each method. All statistical analysis were performed using SAS (V 9.4 m).

Both methods are most strongly affected by the degree of fat saturation, followed by thickness of the belly, although the firmness of the lean also affects the BB.V2 measurement. Although measurements are not interchangeable, if angle limits are chosen carefully, both methods should be suitable for identifying similar firmness categories.

Ethics statements

The authors declare they have abided by all ethical standards of the journal.

No human subjects, live animals, or data from social media platforms have been used in the development of this method.

Image manipulations: Cropping; some brightness and contrast adjustments; annotations.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

B. Uttaro: Conceptualization, Methodology, Data curation, Investigation, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. **S. Zawadski:** Methodology, Data curation, Formal analysis, Investigation, Writing – review & editing. **M. Juárez:** Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

Data availability

Data will be made available on request.

Acknowledgments

The authors would like to thank the Lacombe Agriculture and Agri-Food Research and Development Centre's meat cutting team, and doctoral student Xinyi Wei's contributions to sample preparation and data collection.

This work was supported by Swine Innovation Porc, Projects #1787, and 1237 (Extension).

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