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Are shear force methods adequately reported?

Benjamin W.B. Holman *, Stephanie M. Fowler, David L. Hopkins

Centre for Red Meat and Sheep Development, NSW Department of Primary Industries, Cowra, New South Wales (NSW) 2794, Australia

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ABSTRACT

This study aimed to determine the detail to which shear force (SF) protocols and methods have been reported in the scientific literature between 2009 and 2015. Articles ($n = 734$) published in peer-reviewed animal and food science journals and limited to only those testing the SF of unprocessed and non-fabricated mammal meats were evaluated. It was found that most of these SF articles originated in Europe (35.3%), investigated bovine species (49.0%), measured *m. longissimus* samples (55.2%), used tenderometers manufactured by Instron (31.2%), and equipped with Warner–Bratzler blades (68.8%). SF samples were also predominantly thawed prior to cooking (37.1%) and cooked *sous vide*, using a water bath (50.5%). Information pertaining to blade crosshead speed (47.5%), recorded SF resistance (56.7%), muscle fibre orientation when tested (49.2%), sub-section or core dimension (21.8%), end-point temperature (29.3%), and other factors contributing to SF variation were often omitted. This base failure diminishes repeatability and accurate SF interpretation, and must therefore be rectified.

1. Introduction

Shear force (SF) is a routine instrumental measure used as a proxy for sensory testing for tenderness in meat research. Tenderness is an important characteristic contributing to perceived meat quality and value (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). Trained or consumer-based sensory panels can quantify tenderness, however because of the scale necessary to ensure statistical validity they often exceed the expense and time constraints imposed on researchers. SF is determined using specialised instruments (tenderometers) to measure the mechanical force applied to a meat sample and infer a predefined level of disruption (Purchas, 2014) — for example, the peak force required to sever a sample.

SF is a relatively inexpensive, rapid and reproducible alternative to sensory panels and associations between these two methods have previously been established (Destefanis, Brugiapaglia, Barge, & Dal Molin, 2008; Hopkins, Lamb, Kerr, & van de Ven, 2013; Shackelford, Wheeler, & Koohmaraie, 1999). Building on this association, SF thresholds describing tenderness acceptability to consumers have been developed. Hopkins, Hegarty, Walker, and Pethick (2006) reported 27 N SF as the upper limit for a consumer to deem lamb tenderness satisfactory. Likewise, Aalhus, Jeremiah, Dugan, Larsen, and Gibson (2004) defined 4.9 kg (48.05 N) SF as the upper threshold of beef tenderness satisfaction. However, any comparison to these or other SF thresholds or findings should be made within the correct context to avoid misinterpretation.

Past research has identified several factors to be intrinsic to SF evaluation and act as significant sources for variation. These have been categorised as: 1) Sampling factors, these include species, muscle selection (Shackelford, Wheeler, & Koohmaraie, 1995), carcase side, and sampled portion site or position (Zuckerman, 2002); 2) Preparation factors, which for the most part involves cooking specifications such as temperature, method, portion size and end-point temperature (Wheeler, Shackelford, & Koohmaraie, 1996; Yancey, Wharton, & Apple, 2011), but also includes the fibre orientation and dimension of sub-sections or cores removed for testing (Murray, Jeremiah, & Martin, 1983); and 3) Instrument factors, for instance, instrument selection, blade type and settings (Wheeler, Shackelford, & Koohmaraie, 1997b), and technical replication (Holman, Alvarenga, van de Ven, & Hopkins, 2015). An obvious means to limit these sources of SF variation and ensure better interpretation of SF results is to adopt a unified protocol — and several SF reference methods are already available (Honikel, 1998; Wheeler et al., 1997b). However, due to resource availability and basal differences between research institute protocols and procedures this tactic is presently impractical. It is practical, however, to accurately and comprehensively detail all experimental factors when reporting SF methods as this would facilitate improved reproduction and application.

This study aimed to survey peer-reviewed scientific literature reporting of SF methods with reference to these sources of SF variation,

* Corresponding author.
E-mail address: benjamin.holman@dpi.nsw.gov.au (B.W.B. Holman).

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and in doing so, determine whether the standard at which SF protocols are currently described necessitates improvement.

2. Materials and methods

This approach was based upon that described by Tapp, Yancey, and Apple (2011), but instead identified peer-reviewed scientific journals ($n = 27$) with a scope encompassing 'Agriculture, Dairy and Animal Science' and 'Food Science and Technology' using the ISI Web of Knowledge (Web of Science, 2015) search function. The *Animal Production Science* journal was also included in this list. The search term 'shear force' was then applied to each journal and the generated list of articles were further limited to only those that tested unprocessed and non-fabricated mammal meat SF, with ostrich meat being included as an exception, from the previous seven years (2009–2015).

The data were collected from each SF article ($n = 734$) meeting the above criteria include; journal, first author's listed country – grouped by region (Africa, Asia, Europe, North America, Oceania or South America), and animal investigated – grouped by species (bovine, chevon, deer, equine, ovine, porcine, rabbit and other). Each material and method section was then evaluated for descriptions of instrument (manufacturer and model), blade (type, description), cell load, crosshead speed, SF resistance measured and SF unit, sample (definition, carcase side and portion or site sampled), sub-section or core (type, dimensions, muscle fibre orientation, technical replication), and cooking (method, sample weight, pre-cook status, cook temperature and duration, end-point temperature, and the interval between cooking and SF testing). GenStat 64-bit Release 17.1 (Genstat, 2015) tally function was then applied to analyse the completed dataset.

3. Results and discussion

3.1. Journal, region and species variation

Most SF articles were published in *Meat Science* (54.4%), and the *Journal of Animal Science* (7.9%), *Livestock Science* (6.4%) and *Animal* (4.5%) were, respectively, the subsequent major contributors (Table 1). It should be noted that the *Journal of Muscle Foods* (1.6%) ceased publication in 2010 and therefore contributed SF articles only for two of the seven years surveyed. European researchers supplied 35.3% of all SF articles evaluated, followed by North American (22.3%), Asian (20.2%), and then Oceanian (9.7%) based researchers (Table 1). The majority of the studies (88.3%) were conducted on meat from bovine, ovine and porcine species combined — with bovine (49.0%) contributing the most to this total (Table 1).

Table 1
Percentage of articles (%) from each journal, location (region) of research, and species which tested unprocessed or non-fabricated mammal meat shear force in the survey period (2009–2015).

	%
Journal	
Meat Science	54.4
Journal of Animal Science	7.9
Livestock Science	6.4
Animal	4.5
Asian-Australasian Journal of Animal Science	3.5
Small Ruminant Research	3.3
Animal Production Science	2.6
Canadian Journal of Animal Science	2.5
Animal Science Journal	2.3
Journal of Agricultural and Food Chemistry	1.6
Journal of Muscle Foods[a]	1.6
International Journal of Food Science and Technology	1.5
Journal of Food Science	1.5
Italian Journal of Animal Science	1.2
Animal Feed Science and Technology	1.1
Other[b]	4.0
Region	
Europe	35.3
North America	22.3
Asia	20.2
Oceania	9.7
South America	8.6
Africa	4.0
Species	
Bovine[c]	49.0
Porcine	22.3
Ovine	17.0
Chevon	4.0
Rabbit	2.6
Deer	1.5
Equine	1.4
Other[d]	2.0

[a] Journal of Muscle Foods ceased publication in 2010.
[b] Other journals were: Agricultural and Food Science; Applied Animal Behaviour Science; European Food Research and Technology; Food Analysis Methods; Food Chemistry; Food Quality and Preference; Food Research International; Journal of Animal Physiology and Animal Nutrition; Journal of Animal Science and Biotechnology; Journal of Dairy Science; Journal of the Science of Food and Agriculture; LWT-Food Science and Technology.
[c] Bovine included beef, veal, yak and buffalo.
[d] Other species were: Alpaca; Camel; Llama; Gazelle species; Ostrich; and, Reindeer.

3.2. Tenderometer and blade variation

A total of 31 tenderometer manufacturers were listed in the SF articles. Instron tenderometers (31.2%) were primarily used, and when grouped together with Stable Micro Systems (18.3%), G-R Manufacturing (12.0%), and Lloyd Instruments (6.7%) represented 68.2% of tenderometers reported (Table 2). However, 16.6% of SF articles did not include tenderometer manufacturer details. Likewise, the vast majority of SF articles did not report the tenderometer instrument model (72.9%). When Wheeler et al. (1997a) compared beef SF assessment between five different institutes, a variation in SF was evident between Instron and the other tenderometers used. Unlike this previous study, Hopkins, Toohey, Warner, Kerr, and van de Ven (2010) compared two Lloyd Instrument tenderometers of the same model, from two laboratories that used a similar SF protocol. This study also found SF variation between laboratories, and this suggests either instrumental variation to be based upon calibration differences or operator variation albeit additional research comparing tenderometer manufacturers and models could provide more insight.

The majority of SF articles reported using a Warner–Bratzler blade (68.8%) compared to all other blade types which together accounted for only 6.1% (Table 2). Fundamental design differences exist between many blade types. The Volodkevich jaws and wedge-shaped tooth blades were designed to simulate the act of biting; the slice blade tests for a sharper scissor-like bite; and the Warner-Bratzler acts to shear or cut (Purchas, 2014). Past research has demonstrated associations between SF measures made using different blades (Hopkins et al., 2013; Peachey, Purchas, & Duizer, 2002), and strong correlations to consumer perceptions of tenderness to several blade-types have been observed (Peachey et al., 2002). However, approximately one quarter of SF articles (25.1%) were found to not report the blade type (Table 2). Likewise, additional blade descriptors, such as square, flat, blunt, triangular blade type, were not common and were provided in only 16.2% of all SF articles (Table 2).

The SF unit weight or cell load specifications were not reported in 74.1% of SF articles surveyed (Table 2). Past research that compared cell loadings 10 kg and 20 kg found no difference in SF values (Wheeler et al., 1997a).

Crosshead speed is the constant rate at which a blade moves through a sample, and only 52.5% of SF articles reviewed reported this parameter (Table 2). Past research has shown that when crosshead speed is slowed, the measured SF will be greater (Van Oeckel, Warnants, & Boucqué, 1999; Wheeler et al., 1997a; Wheeler et al., 1997b). The most frequently reported crosshead speed was 200 mm/min (19.2%),