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Review

A review of computed tomography and manual dissection for calibration of devices for pig carcass classification - Evaluation of uncertainty

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ABSTRACT

Online pig carcass classification methods require calibration against a reference standard. More than 30 years ago, the first reference standard in the EU was defined as the total amount of lean meat in the carcass obtained by manual dissection. Later, the definition was simplified to include only the most important parts of the carcass to obtain a better balance between accuracy and cost. Recently, computed tomography (CT) obtained using medical X-ray scanners has been proposed as a reference standard. The error sources of both traditional (manual) dissection methods and the new methods based on images from CT scanning of pig carcasses are discussed in this paper. The uncertainty resulting from the effect of various error sources is estimated. We conclude that, without standardisation, the uncertainty is considerable for all the methods. However, methods based on volume estimation using CT and image analysis might lead to higher accuracy if necessary precautions are taken with respect to measuring protocol and reference materials.

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1. Introduction

Objective online classification of pig carcasses is obtained indirectly by measuring relevant characteristics at the slaughter line. Typically, these characteristics include the back fat thickness and frequently also the thickness of the loin. The characteristics must be measurable and highly correlated with the total lean meat percentage (LMP). It is necessary to use a reference method to determine the parameters of a model that converts the measurands of the online equipment to a predicted value of LMP. This process essentially constitutes a calibration of the online equipment.

Ideally, the LMP should be obtained from measurements including the whole carcass, which is possible when using tomographic methods (X-ray or magnetic resonance imaging). However, the methods are still not available for online measurements. A commonly used online technology is a combined optical insertion probe and a ruler, which utilizes the different reflectivity from meat and fat obtained at near infrared wavelengths. Current online methods are non-invasive and based on, for instance, ultrasound, measuring the reflections from different layers of tissues and fascia. Market harmonisation and the need for transparency resulted in the adoption of EU regulations for objective classification in 1984/1985 (Council Regulation (EEC), 1984; Commission Regulation (EEC), 1985). Although the regulations do not limit the use of technology, they impose requirements on the predictive capability of the methods as evaluated by the quality of calibration. Statistical guidelines (Causeur et al. 2003) propose cost-effective solutions to practical problems related to calibration, including sampling.

1.1. Approved LMP reference methods

The very first common LMP reference method was accepted in 1984. It was adopted from a German dissection method used as the reference method for tissue separation in an international experiment reported by Merkus (1979). The formal definition of LMP is the ratio between the total weight of lean meat in the carcass separated with a knife and the total weight of the carcass. It is a very time-consuming method, and quicker methods were accepted on the national scale until 1994, when a new common simplified reference standard was accepted. The agreement with the previous standard was obtained by introducing a correction factor of 1.3. The accuracy was estimated and reported by Nissen et al. (2006). As a consequence of the results, the method was revised once more in 2008, yielding a higher accuracy. Today, three reference methods are accepted in the EU (Commission regulation (EC), 2008). The first method is a total dissection, excluding the head, which is close to the original definition. The second method is a simplified method defined by the ratio of the weight of lean meat in four main cuts of the carcass plus the weight of the tenderloin and the total weight of the same four cuts and the tenderloin. The ratio is multiplied by a factor of 0.89 to account for the non-dissected parts compared to total dissection. In this paper, total dissection and simplified dissection are referred to as "knife dissection". Recently, it has become possible to use computed tomography (CT), provided an acceptable correlation with knife dissection methods can be demonstrated. No formal requirements explaining what is meant by "acceptable correlation" are provided.

1.2. Computed tomography

In the context of this paper, CT is an X-ray technique used for medical imaging. The use of CT for the study of farm animals is very encouraging. The method has been used for several years in breed selection programmes for lambs in the UK (Bünger et al. 2011) and pigs in Norway (Topigs Norsvin). The method's utility as an objective reference method for online classification was investigated in an inter-European project EUPIGCLASS (2000). Subsequently, several research institutions have acquired a CT scanner designed for human medical use. A list of the actual facilities in 2015 appears in a report from the COST network FAIM (2011). Results and experiences from various investigations have been reported partly as international collaboration within the COST network. The uses of CT data are numerous, for example Clelland et al. (2014), Daumas & Monziols (2011), Font-i-Furnols et al. (2015), Petnehazy et al. (2012), Lambe et al. (2013), Vester-Christensen et al. (2009). This paper is restricted to a discussion of the application of CT as a reference method as an alternative to manual knife dissection.

1.3. Purpose

The purpose of having harmonised rules for classification of pigs within the EU is to provide a reliable and common basis for evaluation of the carcass value expressed as LMP. It is expected that the common rules will ensure that all approved online methods will produce approximately the same results if they can be compared directly on the same carcasses.

Approval of an online classification method is only granted if a satisfactory performance of the calibration for a specific pig population is documented. In this paper, we focus on the uncertainty of the approved reference methods. Lists of uncertainty contributions are drawn up based on available estimates from both published and unpublished experiments conducted during the past ten years, providing a budget of uncertainty of the reference methods. Our purpose is to draw attention to the metrological aspects and, in particular, to identify critical factors that should be standardised to improve the robustness and reliability of the European reference system for online classification of pig carcasses.

1.4. The concept of uncertainty

Measurement imperfection can give rise to an error in the measurement result. The error can be viewed as having two components: a random component and a systematic component. The random effect arises from unpredictable variation, while the systematic effect arises from a recognised effect of an influence quantity. It might be possible to reduce the effect of influence quantities, although, typically, the degree of influence will vary from one situation to another. Consequently, influence quantities will be evaluated based on estimated contributions to the uncertainty together with random error.

1.5. Metrological principles

The uncertainty of the accepted reference standard has been evaluated by a European research group and reported by Nissen et al. (2006). The work used the metrological principles described in the international standard ISO 5725 (2012) and was also inspired by the Guide to the Expression of Uncertainty in Measurements, (BIPM, 2008). The aim of the work was to document the complete chain of uncertainties included in the references.

Traceability is a core concept in metrology. It is defined by the International Bureau of Weights and Measures, BIPM, as "the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties." The concept is illustrated in Fig. 1.

The uncertainty of the standard references for calibration of online measurements will be discussed below in the framework of Fig. 1.

1.6. Type A and Type B estimates

Uncertainty is estimated using two types of variance estimates (see BIPM, 2008). The type A uncertainty estimate is obtained from the experimental variance of observations, which are typically considered as outcomes from a Gaussian distribution. The type B uncertainty estimate is evaluated by scientific judgement based on available information. If