



AN INVESTIGATION INTO THE QUALITY RELATED PRINCIPLES OF THE SOUTH AFRICAN CLASSIFICATION SYSTEM IN RELATION TO GRADING AND CLASSIFICATION SYSTEMS OF THE WORLD

P.E. Strydom^{1#}

¹ARC-Animal Production Institute, Private Bag X2, Irene, 0062. South Africa

Abstract: This paper addresses the principles related to different grading and classification systems of the world with specific focus on quality related outcomes. The paper uses the definitions that classification is a set of descriptive terms describing features of the carcass that are useful as production guidelines and to those involved in the trading of carcasses whereas grading is the placing of different values on carcasses for pricing purposes, depending on the market and requirements of traders.

The literature shows that the criteria used in grading systems rank carcasses fairly accurately according to expected eating experience (<50%) of the loin muscles but not of higher connective tissue cuts of the hind and fore quarter. Criteria used in classification systems give limited descriptions of the quality related characteristics of the carcass. Only the MSA cuts based grading system of Australia seeks to define or predict consumer satisfaction with a cooked meal for each cut of the carcass. Its success is based on a palatability assured critical control point (PACCP) approach to satisfy the consumer. However, MSA requires high technical skills, a well organised infrastructure and proper traceability, high level of integrity from different role players and could be very costly involving high additional personnel cost.

The South African classification system should probably focus on distinguishing between feedlot and pasture animals with different criteria within each sub category to describe the variation in product quality.

Keywords: classification, grading, beef

Corresponding authors: E-mail: pstrydom@arc.agric.za

Introduction

Carcass grading or classification was established in most prominent meat producing countries during the early to middle 1900's. Over time the evolution of these systems were driven by new problems/needs or changes in production systems. The primary motivations for the development and implementation of these systems are best summarised in a report of AHDB Industry Consulting on the EU classification system (AHDB Industry Consulting, 2008):

- Poor market transparency, made even more difficult by a fragmented industry
- Poor market intelligence with regard to guidelines for price formation
- A lack of a common descriptive language for a highly variable product
- Production led (as opposed to market led) mainly the result of a lack of production guidelines
- Lack of consumer confidence in the retail product caused by among other things lack of precise description at the retail level, poor labelling and marking

Therefore the general aims and objectives of carcase classification or grading system would be close to those quoted by the same report:

- To provide a common language for use by those in trading livestock and carcasses to facilitate trade and intensify competition;
- To develop clearer market signals from the consumer to the producer by the use of premiums for desirable stock and discounts for less desirable stock;
- To act as a catalyst for breed and national herd / flock improvement;



- To act as a framework for the development of national price reporting schemes to enable those trading (and others such as statutory organisations) to determine what prices were paid for differing types of stock in different areas;
- To assist producers to market their stock more effectively, aided by better ‘market transparency’;
- To improve efficiency in transactions in what is today referred to as the ‘supply chain’ between producer, slaughterer and retailer; encouraging buying specifications to be used that could be filled and verified against classification descriptions.;
- To allow those cutting meat to monitor and control their operations on a yield basis. Classification has a direct relationship with the amount of saleable meat in a carcass. Yields and returns from cutting and processing can therefore be predicted and monitored with a knowledge of the classification of the carcass raw material;
- To promote, by the marking or labelling of classification/grading information on meat up to the point of retail sale, a basis for ‘quality’ marks or promotional brands;
- To facilitate the development of any export markets.

From these it is clear that carcass classification or grading systems have been invented and are continuously being developed to describe the quality and yield of a carcass (in particular the edible part) to the benefit of all role players in the production chain and for the final purpose of a satisfied consumer. Smith, *et al.* (2008) describes the consumer process in terms of firstly a “customer” (person who purchases) whose preference is influenced by appearance characteristics (e.g. ratios of muscle, fat and bone, amount of marbling; colour of fat and lean; freedom of defects). The quality of cooked meat is then evaluated by a “consumer” in terms of palatability characteristics (e.g. flavour, juiciness, tenderness). Therefore both yield factors (fat, bone, meat) and eating quality will influence consumer preferences, but most consumer surveys suggest that eating quality (defined by most consumers simply as ‘taste’) is a primary driver of food purchase decisions (Quinn, 1999; Tatum, 2006; Shook *et al.*, 2008).

While the aims and objectives of grading and classification are broad, the uptake by sectors of the industry will probably depend on factors such as:

- Accuracy - it will sort beef carcasses into meaningful and marketable groups using applied science.
- Simplicity - All segments of the industry must have a working knowledge of the system.
- Ease of application - It can be implemented with a minimum amount of time and effort – most of the time in-line or at least before the carcass is sold.
- Cost - It does not require expensive equipment.
- Measures against tampering – it should be easy to monitor or verify correctness and once a grade/class is awarded it can not be changed.

The aims of this document is to give a short overview of the grading and classification systems of the world, then to identify the criteria in these systems involved in the description/prediction of eating quality. Successes and/or shortfalls related to these criteria will then be discussed with specific reference to the South African system.

The definitions proposed by AHDB Industry Consulting (2008) are adopted in this paper. Classification is a system that describes all of the scores or measurements for important traits. The carcass is then presented for trade listing all the attributes that have been evaluated. Grading is defined as the placing of different values on several carcass characteristics and using different combinations of these characteristics to develop a grade for pricing purposes, depending on the market and requirements of traders. Generally this involves ranking carcasses in a hierarchy for the traits of interest.

A brief summary of beef classification and grading schemes of selected countries around the world and criteria used in these systems

Globally certain countries or regions have focussed more on yield (EU carcass classification scheme; AHDB Industry Consulting, 2008), others have adopted a dual system attempting to describe or grade both yield and quality (USDA carcass grading scheme - Smith *et al.* 2008; South African carcass classification scheme - Government Notice No. R.342 of 19 March 1999; the AUS-MEAT system - Anon, 2006) or meat quality/palatability only (MSA cuts based grading - Polkinghorne, *et al.*, 2008).

The history of the origin and evolution of major grading and classification schemes of the world were reviewed by Polkinghorne & Thompson (2008) and will not be repeated in detail in this document.



However, Table 1 was adopted from this work and describes the principal components of these schemes and also distinguishes between grading and classification systems and operational area.

Of the 7 countries discussed, only the European (EUROP), South African (SA) and the AUS-MEAT system of Australia is regarded as classification systems. Of the grading systems, all but the Meat Standards Australia (MSA) cuts based grading systems have separate yield and quality grades. The latter system will be discussed later in more detail due to its unique nature.

In terms of “Ease of application”, the AUS-MEAT and MSA are the only systems using pre-slaughter criteria, while these 2 and the other grading and classification systems perform measurements on the slaughter floor. Chiller assessments, in addition to slaughter floor assessments, are used by all but the EUROP and SA systems, while the MSA system does post-chiller recordings

Conformation, shape or rib eye area (REA), some form of fat measurement, carcass weight and sex are common criteria for all systems and are recorded on the slaughter floor and/or during chiller assessment. All except sex are used for yield predictions but are also incorporated into quality grades in grading systems and to lesser extent it contributes to descriptions related to meat quality (such as the SA system).

Age or maturity, and marbling seem to be the main criteria used for quality grading and classification. Age or maturity is determined by dentition in the SA and AUS-MEAT systems. MSA, Canadian and USDA use ossification score, instead and other characteristics that may be used to (but not limited to) describe maturity are meat texture, meat colour (or brightness) and lean maturity and are used by the MSA, USDA, AUS-MEAT, Canadian, Korean and Japanese. The Korean system uses ossification in their yield grades. Fat characteristics are also used for quality grades by the Canadian, Korean and AUSMEAT systems, while the Japanese system include fat lustre, firmness, and texture (Beef Fat Standards – BFS). All fat and meat/muscle appearance, quantity and texture scores are performed visually or with the aid of standards (charts).

The combinations in which the scores for the various characteristics are used to form a quality grade are rather interesting and are described in more detail by Polkinghorne & Thompson (2010) and Smith *et al.* (2008). A few could be mentioned which have relevance to further discussion in this document.

The USDA system is well-known for using marbling as one of its main criteria in combination with maturity and type/sex of the animal. The Official United States Standards for Grades of Carcass Beef define ‘quality grade’ as ‘the palatability indicating characteristics of the lean’, and state that: ‘for steer, heifer and cow beef, quality of the lean is evaluated by considering its marbling and firmness as observed in a cut surface in relation to carcass evidences of maturity. The 8 quality grades are Prime (Pr), Choice (Ch), Select (Se), Standard (St), Commercial (Co), Utility (Ut), Cutter (Cu) and Canner (Ca) for which there are firstly gender and type limitations (e.g. bulls are not quality graded, cows can not be graded Prime and bullocks are graded separately from steers, heifers and cows). The first 3 grades are mostly related to retail table cuts. After distinguishing sex and gender, grades are formed by combination of marbling and maturity in such a way that the higher the maturity (older), the stricter the marbling scores, i.e. the marbling cut-off category for Choice is higher than for Prime and so on so that more mature carcasses have to make up for age by having more marbling, so to speak. Maturity is determined by evaluating the size, shape and ossification of the bones and cartilages – especially the split chine bones – and the colour and texture of the lean flesh. Five maturity groups (A-E) are used with “position within each group” (e.g. A⁰⁰, A²⁰...A¹⁰⁰) determined by ossification of split chine bones of the vertebral column, size and shape of rib bones (becomes wider and flatter with less blood in old animals), colour of muscle (older becomes darker), and texture of muscle (older becomes coarser). Nine marbling scores are used abundant (AB), moderately abundant (MA), slightly abundant (SA), moderate (MD), modest (MT), small (SM), slight (SL), traces (TR) and practically devoid (PD) based on amount, size of blots and distribution of blots. The percentage of intramuscular fat is 1.8 for the lowest marbling degree (PD), increases 1.2 per degree, and is 11.7 for the highest marbling degree (AB) (Savell *et al.*, 1986; Lunt *et al.*, 1989).

.The Canadian system distinguishes between youthful and old (cows and bulls) by ossification with grades for each of the two categories. Other measurements like fat colour, and lean texture and colour are used to further distinguish grades in both categories. Top youthful grades exclude yellow fat and require better muscling and firm lean texture. One grade is reserved for bulls.



Table 1 Principal components of selected beef classification and grading schemes in selected countries around the world

Country	Canada	Europe	Japan	South Korea	The Republic of South Africa	USA	Australia	
Scheme	Canada	EUROP	JMGA	Korea	South Africa	USDA	AUS-MEAT	Meat Standards Australia
Grading Unit	Carcass	Carcass	Carcass	Carcass	Carcass	Carcass	Carcass	Cut
Classification	--	Yes	--	--	Yes	--	Yes	--
Quality Grade	Yes (4) + (5)	--	Yes (5)	Yes (5)	--	Yes (8)	--	Yes (3)
Yield grade	Yes (3)	--	Yes (3)	Yes (3)	--	Yes (5)	--	--
Pre-slaughter	--	--	--	--	--	--	Grain fed	<i>Bos indicus</i> % HGP implants
Slaughter floor	Carcass weight	Carcass weight Sex	Carcass weight	Carcass weight	Carcass weight Dentition	Carcass weight	Carcass weight Dentition	Carcass weight Sex
	Sex Conformation	Fat cover Conformation	Sex	Sex	Visual fat cover Conformation Sex	Sex	P8 fat Sex Butt shape	Electrical stimulation Hang
Chiller	Marbling score Meat colour Meat texture Fat colour Fat thickness Skeletal development	--	Marbling score Meat colour Meat brightness Fat colour Fat luster Fat texture Fat firmness EMA Rib thickness Fat thickness	Marbling score Meat colour Fat colour Firmness Meat texture Lean maturity EMA Fat thickness	--	Marbling Ossification score Meat colour Meat texture Rib fat EMA Kidney and perirenal fat	Marbling score Meat colour Fat colour	Marbling score Ossification score Meat colour Hump height Ultimate pH
Post Chiller	--	--	--	--	--	--	--	Ageing time Cooking method



It is interesting to note that quality grades used by the Korean and Japanese systems do not include age of the animal per sé (dentition or ossification score). The Japanese system uses the scores of all 7 quality parameters mentioned in table 1 to allocate carcasses to 1 of 5 quality grades. The same applies to the Korean system but with 6 parameters.

The British and rest of Europe's classification systems evolved over many years and were combined into a single system (EUROP) in 1981 (AHDB Industry Consulting, 2008) with the main objective to describe carcasses for those involved in slaughtering, cutting, distribution and retailing according to terms relevant to trading. At the time of the schemes' development it was appreciated that meat quality, in all its guises, was of importance to the meat trader and also of principal interest to the consumer in the form of eating quality. However, they argued that since no practical, reliable and cost-effective measure emerged from many research initiatives over years, the system remained focussed on yield classification. The procedures like those captured in the MLC Blueprint in the United Kingdom for quality beef could be adopted by sectors of the industry to ensure quality (AHDB Industry Consulting, 2008). The French as another example use official quality and origin signs as quality indicator on products, such as "Organic farming" or "Label Rouge". These are therefore audited brand marks aiming at describing authenticity or controlled processes like in the MLC Blueprint and do not include quality identifiers. To the Europeans, the final decision regarding the inclusion of quality in classification was to describe quality accurately by single or combined carcass parameters, or leave it out of the system.

In the interest of the scope of this document, the history of the SA system will be described a bit more thoroughly. The SA beef description system has also evolved over a number of years from 1932. Age of the animals has been used since 1936 as a characteristic to grade carcasses, presumably because carcasses of younger cattle were considered to be of "better" quality than those of older cattle (Government Notice No. 1548 of 1936). Permanent incisors was used for the first time in 1949 when "A" indicated carcasses of younger animals with not more than 6 teeth and "B" indicated carcasses of older animals with more than 6 teeth, but which were not older than 4 years (Government Notice No. 992 of 1949). In 1951, a class "C" for carcasses of the oldest animals was used for the first time (Government Notice No. 846 of 1951). In 1970, the "Super A" grade was allocated only to carcasses of animals with no permanent incisors and the "Super B" grade only to carcasses of animals with 1 tooth or more, but with not more than 4 teeth (Government Notice No. 1730 of 1970). Less than a year later, the grades "Super A" and "Super B" were combined as "Super" for carcasses deriving from animals with not more than 2 teeth. The age class "A" was used in the grades "Prime A" and "1A" for carcasses of animals with no more than 2 teeth; the age class "B" in the grades "Prime B" and "1B" was allocated to carcasses which derived from animals with not less than 3 and not more than 6 teeth, and the age class "C" in the grade "1C" to carcasses which derived from animals with more than 6 teeth, not older than 5 years (Government Notice No. R.1239 of 1971). In the research of Klingbiel (1984) it was found that A-age animals had significantly higher muscle collagen solubility, that muscle pigment concentration was significantly lower, and that the cooking loss (%) was significantly lower. These results would be generalised by saying that the meat of A-age animals (not more than 2-teeth) was more tender, lighter coloured and juicier than meat from older animals. Through a series of discussions by various working groups and committees a proposal was accepted to define the age classes as A: 0-tooth; B: 1- to 6-teeth; and C: 7- to 8-teeth (Government Notice No. R.1010 of 1981). The Namibian Carcass Classification System is still based on these principles in attempt to ensure the production of consistent quality meat (tenderness and fatness). Further research in the early 1990's confirmed previous work and showed that meat tenderness decreased, as the slaughter age of the animals increased, in the order of 0, 2, 4, 6 and 8 permanent incisors. Samples of meat from animals with no permanent incisors were significantly more tender than those of the animals with 2 permanent incisors. The 2, 4 and 6-teeth animals were not appreciably different in terms of tenderness. Fat content did not affect the tenderness results (Crosley *et al.*, 1994). In spite of these results, some still denied their validity and exerted pressure on the authorities to eventually classify the carcasses of 2-teeth animals in a separate age class (AB) than the 3- to 6-teeth animals (B) and 0-tooth animals (A) (Government Notice No. R.342 of 1999).

The Australian system described as both MSA and AUS-MEAT in table 1 seems confusing, but in fact describes two interrelated parts of a common system. Initially, Australian grading described grading standards in terms of conformation, fat cover and age as first, second and third grade implying a decrease in quality (Anon, 1974). This was later replaced by the AUS-MEAT language reflecting a deliberate change from a subjective quality rating to a specification in terms of sex, dentition and carcass weight without any



connotation to quality. The reasoning behind this classification (not grading) was that to different sectors, different specifications translate to top quality, e.g. the hamburger market will rather use fatter older animals, while the restaurant trade, needs younger, leaner carcasses. The AUS-MEAT system evolved further over years with the inclusion of chiller assessment standards for fatness, marbling, meat colour, fat colour, REA (Anon, 2006). Other developments also include precise descriptive language for carcass cuts and collectively these serve the domestic but especially the export trade. With the recent development of the MSA cuts based grading system for the domestic market, the base components of AUS-MEAT (sex, dentition, carcass weight and rib fat) proved ineffective as predictors of eating quality and additional refined factors were added including ossification and marbling. Pre-slaughter inputs including *Bos indicus* content, the use of hormonal growth promoters (HGP) were added together with processing factors such as carcass suspension method (tenderstretch), and post mortem pH/temperature decline. Finally, post processing inputs of days aging and cooking method by muscle were added (Polkinghorne, *et al.*, 2008). The descriptive language for these traits is captured in AUS-MEAT documentation.

How do these systems perform and how reliable are their criteria?

Various studies have investigated the accuracy of classification or grading criteria to predict or describe quality or to rank carcasses according to quality. All of these studies have their limitations simply because all factors can not be addressed in a single study, or the measuring tools used are not faultless and/or very often these subjects are addressed from a specific industry's perspective.

Maturity measured by ossification (with or without lean maturity) or dentition, and marbling are probably the most common criteria used in all quality grading or classification systems. Smith *et al.* (2008) gave a thorough overview of the suitability of the USDA system (using both maturity and marbling) as grading system. Smith *et al.* (2008) reports that the philosophy used in the grading of any agricultural commodity involves sorting of the products into groups – usually in some hierarchical fashion that differ in utility, desirability and value. The authors emphasise the fact that the USDA quality grades were never intended to provide point estimates for expected beef palatability and that neither quality grades nor palatability ratings are perfectly assigned because both are subjective estimates. Furthermore a single muscle is used as reference or predictor of the whole carcass. There are numerous studies that evaluated the USDA system for various measures of efficiency and suitability. From most of these it is important to note that not only tenderness is evaluated but rather the grading systems effect on overall experience, palatability or acceptability that includes other measurements such as flavour, juiciness, visual appeal, etc. Only a few relevant to this discussion will be reviewed. The study of Smith *et al.* (1987) describes the ranking ability of the system across all the grades and reports that USDA quality grades (marbling and maturity) only accounted for 40 to 47% of the observed variation in overall palatability (sensory scores) of dry heat-cooked (broiled) loin and top round steaks (topside) and 25 to 33% of the variation in shear force (mechanical measurement for loin, top round (topside), bottom round and eye-of-round steaks (silverside). The difference between the two prediction values also indicates the effect of measuring tool (shear force vs. sensory panels). Mean overall palatability ratings (sensory scores between 1 and 8) for loin steaks were 6.0 (Pr), 5.7 (Ch), 5.3 (Se), 4.6 (St), 4.9 (Co), 4.0 (Ut), 3.4 (Cu) and 2.8 (Ca) with $P < 0.05$ significance for differences across the categories, except for Cu and Ca. When all sensory panel ratings (tenderness, connective tissue, flavour, juiciness) and shear force values were combined in a single “desirability” score, percentages of loins steaks rating “very desirable” were 63.6 (Pr), 49.4 (Ch), 35.3 (Se), 20.3 (St), 30.3 (Co), 11.1 (Ut), 3.2 (Cu) and 0.0 (Ca). Smith *et al.* (2008) report that in the USA the beef quality grades actually used in commerce are those for carcasses from cattle less than 42 months of age (nominally) – Pr, Ch, Se, with St essentially never sold as such at retail because of the negative connotation of the term. Quality grade predicted flavour, tenderness, and overall palatability of loin steaks with 30-38% accuracy, but could not explain more than 8% of variation in panel ratings of the top round (higher connective tissue).

With regards to marbling and when only the top maturity classes were considered (A and B), the percentage of steaks with a composite of sensory panel ratings (overall palatability, flavour, tenderness, juiciness) of ≥ 6.00 and a shear force value of ≤ 3.63 kg (margins for acceptability) was 66, 59, 56, 48, 41, 33, 21 and 15% for loin steaks and 18, 19, 5, 13, 8, 12, 5 and 8% for round steaks (topside or silverside) from carcasses with moderately abundant (MA), slightly abundant (SA), moderate (MD), modest (MT), small (SM), slight (SL), traces (TR) and practically devoid (PD) marbling, respectively (Smith *et al.*, 1984).



Therefore the effect of marbling on acceptability and its ability to rank was more evident in loins than in round steaks (topside, silverside) and also showed more significant changes over marbling levels for the loin. Furthermore, the effect of marbling (measured in the loin) on palatability of round steaks were less than for the loin especially at lower levels which suggests that connective tissue effects became more prominent. Considering the acceptability scores reported above it is interesting to note that less than 21 % consumers in the study of Smith *et al.* (1984) would have regarded loins typical to the SA market as acceptable since the % marbling is generally less than the 3%, which is the average marbling for the TR marbling class (second from bottom).

On maturity scores, Smith *et al.* (1984) reported that A-maturity carcasses produced 'very desirable' loin steaks 1.2, 1.5 and 8.0 times and 'acceptable' loin steaks 1.0, 1.1 and 1.6 times as often as did carcasses of B, C or E maturity carcasses respectively. For round steaks (with higher collagen) 'very desirable' scores were given 3.0, 3.3 and 5.7 times, and 'acceptable' scores 1.4, 1.5 and 3.1 times, respectively as often in A-maturity compared with of B, C or E maturity. Therefore up to 72 months of age and even older carcasses, consumers regarded loin as very similar in terms of "very desirable" or "acceptable, but maturity scores differentiated more clearly in high connective tissue cuts, which is to be expected and also reported for the SA classification system (Klingbiel, 1984). Using one muscle as indicator seems to be a common problem in grading and classification systems. In this regard, Smith *et al.* (2008) reviewed several studies involving the loin muscle as single predictor muscle and concluded that the loin (*m. longissimus*) is an imperfect but very useful predictor of the tenderness of most of the major muscles in the beef carcass.

Dentition probably describes chronological age of the animal the best despite variations experienced among breed types and nutritional plane (Steenkamp, 1970; Weiner & Forster, 1982; Lawrence *et al.*, 2001). Lawrence, *et al.* (2001) regards a dentition based system more accurate than the USDA maturity-based (bone ossification/ lean maturity) system to sort carcasses into age groups. Furthermore, they reported that cattle with 2, 4 6 and 8 incisors were placed in more youthful categories of USDA maturity groups than they should have. In fact, 40% carcasses with 8 incisors were still classed as A maturity in the USDA system. Other studies (e.g. Rodas-Gonzalez *et al.*, 2009) reported a better correspondence between USDA based maturity scoring and dentition based age in a study testing tenderness thresholds on Venezuelan cattle. This study did not address the effect of age or maturity on consumer acceptability, but another Lawrence, *et al.* (2001) found very poor relationships between shear force or sensory panel tenderness of the loin muscle and age classed according to dentition. Strangely, USDA maturity scores, marbling scores and colour scores also correlated poorly with sensory scores but showed significant correlations with Warner Bratzler shear values. Wythes & Shorthose (1991) reported a similar lack in shear force differences among dentition groups of cattle from Northern Australia and stated that part of the reason could have been that younger animals were leaner, chilled faster and therefore were subjected to myofibrillar shortening (cold shortening). Shorthose & Harris (1990) avoided the cold shortening effect by application of electrical stimulation and reported an age related decrease in tenderness (shear force and sensory panel) as age progressed from 1 to 60 months. In Australia MSA elected to move away from dentition score as indication of age/maturity of the AUS-MEAT and use weight for age and ossification score, instead. The SA system has relied on dentition as only parameter to categorise (or describe) carcasses into potential tenderness groups since 1949. As reviewed earlier in this document, changes in the definitions or criteria of age classes varied over years until the latest adjustment was accepted in 1999 that 0, 1-2, 3-6 and >6 permanent incisors will distinguish A, AB, B and C age classes. This was despite earlier findings that showed the A class was significantly more tender than the other classes for the *m. longissimus* (loin) and *m. gluteo-biceps* (silverside) (Crosley *et al.*, 1994). Carcasses with 2, 4 and 6 permanent incisors did not differ significantly in sensory panel scores for the loin muscle, although mean values decreased numerically. Shear force values were not different among age groups (0 to 8 incisors) and large variations within age group occurred. Carcasses used in the study were all electrically stimulated, were of similar weight and fatness and no pH abnormalities occurred (too high pH). Differences in the sensory scores and shear values were more pronounced between the 0 tooth group and the 2, 4 and even 6 teeth groups, when a muscle, *m. gluteo-biceps*, with higher collagen content was used. Bouton *et al.* (1978) and Shorthose & Harris (1990) reported similar results and also emphasised that method of cooking, type of muscle, restriction of shortening of the muscle (through suspension method or electrical stimulation) interacted with one another, bringing out various results with regard to differences in age. Nevertheless, they concluded that the older animals get, the tougher the meat mainly due to connective tissue hardness or heat stability, hence the greater effect on high connective tissue muscles.



The same line of reasoning were later adopted by Polkinghorne, *et al.* (2008) when they developed the MSA beef grading system, which will be discussed later. Regarding muscle type and age related tenderness, Shorthose & Harris (1990) reported that the deep breast muscle (*m. pectoralis profundus*), and some muscles from the buttock (*m. gluteobiceps* and *m. semitendinosus* of the silverside) were unacceptably tough before 2 years of age, the *m. vastus lateralis* and *m. rectus femoris* of the knuckle and *m. semimembranosus*, *m. gracilis* and *m. aductor femoris* of the of the topside became unacceptable after 2 years of age. The loin (*m. longissimus*)(LD), fillet (*m. psoas major*) and rump (*m. gluteus medius* and top *m. gluteo biceps*) were acceptable in tenderness up to 48 months of age which coincide with 6 to 8 permanent incisors. The benchmark for acceptability is of course ambiguous but nevertheless this work demonstrates the relative effect of age on tenderness. For this study, they merely used a value as cut-off point for acceptability while classification would rather describe the product and grading would categorise and relate the product to various levels of satisfaction potential. Shorthose & Harris (1990) also found that the LD is a very poor muscle to use as reference for prediction of tenderness. South African work completed at the same time as the work of Crosley *et al.* (1984) but published recently confirmed an age related increase in heat-stability of connective tissue (collagen) and that the higher the collagen content of a cut, the more it will be affected by age even when the correct cooking method is used (moist heat cooking) and even when the collagen solubility is high.

While age by dentition is the only quality related criteria in the SA classification system, sufficient evidence exist to show that factors other than age (extrinsic or intrinsic) may have an effect on tenderness. These factors may even overshadow the effect of age depending on the type of muscle (muscle composition in terms of fibre type and connective tissue content) and position in the carcass (which relate to shortening of the fibres) and environmental conditions and inputs. In two recent studies, effects of age, production system (including nutrition) and abattoir practice on tenderness were investigated (Van Wyk *et al.*, 2008; Frylinck *et al.*, 2009) (Figure 1).

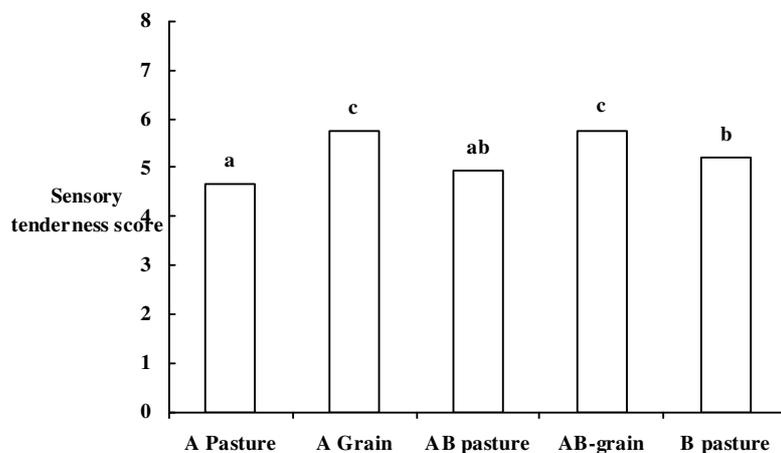


Figure 1 The effect of age class (by dentition) and production system on sensory tenderness scores of *m. longissimus* (^{a,b,c} Bars with different superscripts differ significantly, $P < 0.05$; Sensory tenderness: 1 – extremely tough; 8 – extremely tender)

Loin steaks of carcasses of feedlot animals with either 0 (Class A) or 2 (Class AB) incisors were more tender (sensory panel and Warner Bratzler shear force) than steaks of loin steaks of carcasses coming from pasture animals aged according to incisors from 0 to 6 or A, AB and B age classes. Among the pasture animal groups, animals with no permanent incisors (A class) produced tougher steaks than animals with 3 to 6 incisors (B class) and animals with 3 to 6 incisors had numerically better tenderness scores than animals with 1 to 2 incisors (AB class). The poor performance of the very young pasture animals (A class) could be related to poor conditioned small carcasses which reflects poor growth rate and chilled faster and therefore was prone to cold shortening of the loin (even though electrical stimulation was applied).



Perry & Thompson (2005) and Shackelford *et al.* (1994) reported more tender meat for faster growing animals within the same group, which Shackelford related to lower calpastatin activities (hence better aging ability of muscle). Purchas *et al.* (2002) reported similar effects and stated that growth path (i.e. growth rate determined by feeding) or growth potential (genetic) had the same effect, namely older animals and poorer market condition for slow growers, but interestingly they also showed an advantage in aging potential of fast growers but gave no results on connective tissue properties. In another study by Strydom (2005) the effect of electrical stimulation and aging over feeding regime and age category was demonstrated. Stimulated carcasses produced more tender loin steaks generally (over all age groups). No significant differences were recorded between 0 (A class) and 2 incisors (AB class) for pasture and feedlot and 4 and 6 incisors (B class) for pasture animals, but the older groups recorded numerically lower scores (Figure 2). Eight (8) incisors (C-Class) scored significantly lower sensory tenderness scores. For non-stimulated samples, much more variation occurred within (data not shown) and between age groups, and 2, 4 and 8 incisor groups gave the lowest scores (Data not shown). Stimulation had a significant effect on loin tenderness for all age groups. Both these studies demonstrate that correct abattoir practice and/or nutrition/growth rate could affect tenderness as much or more than age of the animal, at least for the loin muscle (since other muscles were not evaluated)

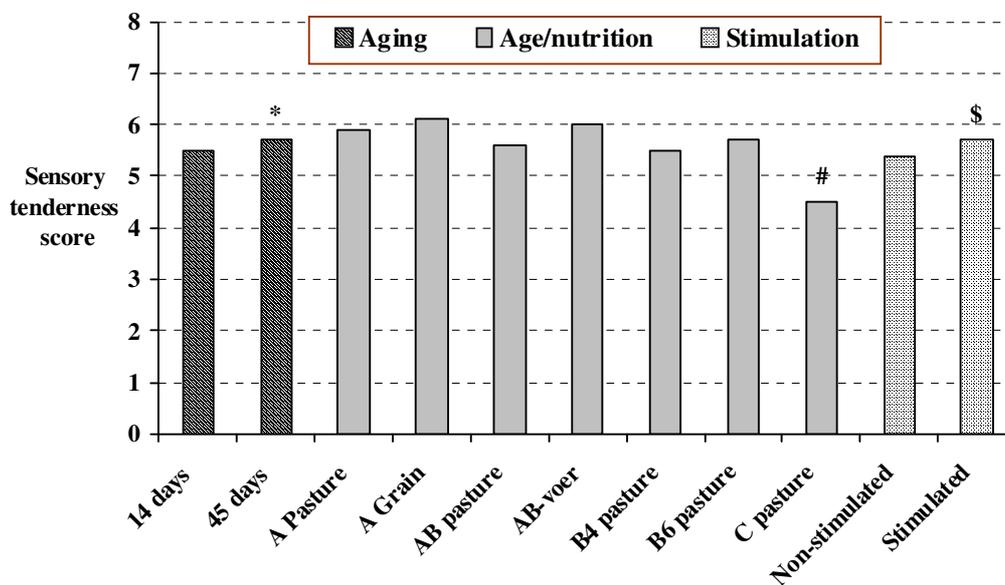


Figure 2 The effect of age class (by dentition), production system, electrical stimulation and prolonged *post mortem* aging on sensory tenderness scores of *m. longissimus* (* - 45 days significantly more tender than 14 days; # - C-pasture significantly tougher than all other age groups; \$ - Stimulated significantly more tender than non-stimulated; $P < 0.05$)

When the present classification system in South Africa was established and developed, the changes that took place over time (as described earlier) probably reflected the changes that occurred in industry, such as the introduction of feedlots in the 1970's that increased the production of young grain fed cattle. The criteria used at the moment were also established during a time when production systems were fairly standard and most animals were slaughtered in large state owned abattoirs that operated according to the same standards in terms of pre-slaughter (lairage time), slaughter (electrical stimulation) and post-slaughter (chilling) procedures. In the past two decades, much has changed when the industry deregulated, production processes changed and an increased integration of production, slaughtering and processing occurred. Therefore it could be argued that age classification alone may not be as sufficient anymore to describe a product with regard to quality, more specifically tenderness, as two decades ago because effects other than age and a lack of consistency in the inputs before and during slaughter of the animal may have a greater



effect on the final product quality than age. Considering the feedlot industry that represents the largest portion of carcasses produced in the SA market, hormonal growth promotants (HGPs) are widely used. Studies have shown variable effects on tenderness and eating quality, differences are often small and difficult to measure and are influenced by the number and type of HGPs used, animal breed and duration and type of post-slaughter treatment such as aging (Hunter, 2010). It was however concluded by Watson *et al.* (2008c) and Hunter (2010), in controlled studies that they do have a negative effect especially with repeated applications, combination of substances and aggressiveness of substances. Nevertheless, judged by the magnitude of their effects, the use of beta agonists (always in combination with HGP) that were only introduced at the end in the late 90's to early 2000, has a much greater negative effect on eating quality (tenderness specifically) (Dunshea *et al.*, 2005) and while abattoir procedures (such as electrical stimulation) and post mortem aging overcome most of HGPs' effect, this is not achieved with beta agonists (Hope-Jones, *et al.*, 2010).

When the variation in procedures before, during and after slaughter is considered the problem becomes more complex. Electrical stimulation has been discussed in relation to age but its true effect is only revealed when both the comparisons of stimulation vs. no stimulation and the correct application of stimulation are taken into account. Referring back to the state owned abattoirs of two decades ago, the slaughter process (including stimulation) was standardised, while today various scenarios (no stimulation, ineffective stimulation, over stimulation) of incorrect procedures occur due to the fragmented industry and smaller units. The impact of this state of affairs is demonstrated by various studies (Strydom *et al.*, 2005; Hwang, *et al.*, 2003; Hwang & Thompson, 2001(a), (b)).

There are of course methods and systems well documented to overcome most of the variation in final quality. The question remains whether these "control" measures should form part of a grading system and if it is practical to integrate them into a grading system. Bindon & Jones (2001) describe the Australian industry as very similar (though on a larger scale) to that of South Africa with diverse base of climatic extremes, a large breed and breed cross diversity, including a proportion of high *Bos indicus* content, animal management systems and slaughter and processing facilities. These combinations of different cattle type, age and production system all contribute to extreme variability in carcass quality experienced by the Australian consumer in the 1990s with added effects of variation in cut properties and cooking procedures. (Polkinghorne, *et al.*, 2008). The development and evolution of the MSA beef grading system followed with the industry identifying two key strategic imperatives for a meat industry strategic plan: to supply a more consistent product and to accurately describe palatability. Taking this into consideration, several key issues needed to be addressed, viz:

- The consumers' reference framework (terms of reference) for eating quality had to be the same to make an attempt to guarantee quality.
- How should consumer standards be set?
- How should product quality be measured?
- Did the existing grading systems perform?

The last two questions relate to the main objective of our discussion, while the first two relate to consumer experience and relation to grading or classification. Strictly speaking the implementation of the system was not only for grading purposes but to uplift the whole image of beef to the consumer. Smith *et al.* (2008) describes the system as a) one with a quality control mentality incorporating production or processing factors that affect beef palatability, and b) allowing mid-course correction in the product of harvest animals. This is in contrast to systems such as the USDA and other grading and classification systems that rely solely on after-the-fact sorting based only on differences in quality-indicating carcass traits.

The MSA grading system has been developed to predict the eating quality of individual cuts when aged for a defined number of days and cooked by a specified method (Watson, *et al.*, 2008a). The prediction is made by a computerised model that calculates the interaction of a range of inputs to produce an MQ4 score (a consumer score incorporating flavour, juiciness, tenderness and overall acceptability, four variables) expressed in points between 0 and 100. Grades are assigned to each cut on the basis of estimated MQ4 points with those <46 deemed unsatisfactory, 47–63 graded three star (good every day), 64–76 graded four star (better than everyday) and >76 graded five star (premium quality)(Figure 3). There is therefore no carcass grade as such. The inputs mentioned above have been researched and found as major contributors to final quality and satisfaction of the consumer. Pre-slaughter issues are breed, weight for age and growth rate,



hormonal growth implants (HGPs), marbling and fatness, gender, stress and management practices. Post-slaughter practices are pH and temperature paths, hanging and aging and cooking method. The inclusion of each factor is discussed and motivated at length by Polkinghorne, *et al.* (2008) and Watson *et al.* (2008a). The following gives a brief description of the effect of each factor as motivated through numerous research trials:

- a) A negative relationship exist between eating quality of the loin and levels of *Bos indicus* content, while no significant differences in eating quality is found among British and continental breeds. MSA measures the amount of indicus by scoring the % *Bos indicus* before slaughter and measuring the hump (*M. rhomboideus*) height after slaughter. A certain cut-off value is used to prevent accidental penalisation of certain *Bos taurus* breeds.
- b) As discussed earlier, research showed that animals growing faster within a group (the same age) produced more tender meat. Dentition was found to be a poor predictor of quality related to age and therefore ossification scores are used combined with the weight of the animal within its age, therefore indicating its growth rate. Most carcasses for the domestic markets in Australia are relatively young and fall into the A maturity group.
- c) Consumer data confirm a relationship between marbling and consumer scores which varied widely among cuts. Watson *et al.* (2008(b)), and Thompson (2004) reported that marbling alone explain a consistent but relatively low proportion (15 – 20%) of the variation in consumer or trained panel scores of the loin muscle but little of the variation among cuts in the carcass is explained by marbling. In addition to marbling fat, a minimum rib fat thickness of 3 mm is used as censoring variable.
- d) HGPs were found to have negative effect on eating quality, that it varied by muscle and the effect was reduced, but not eliminated by aging (Thompson *et al.*, 2008(a); Watson, 2008; Watson *et al.*, 2008(c)). It also showed a breed type x HGP interaction and that HGPs affected marbling and ossification separately.
- e) The effect of gender on eating quality was small but was nevertheless included and differentially applied for various muscles and further adjusted according to ossification (Watson *et al.* 2008(b)). Bulls would not be included.
- f) Various studies (Butchers *et al.*, 1998; Ferguson *et al.*, 2007(a), 2007(b)) describe the effect of stress on, not only tenderness, but also juiciness. Stress is recorded by the origin of the animals, time off feed, and by time restrictions for mixing of groups of animals. Top grades animals are not allowed from sale yards and should be transported to the abattoir directly from the producer. In addition, a final pH value of 5.7 is used as cut-off criterion and indicator of stress history.
- g) Post slaughter conditions (pH change and chilling rate) have been described by Dransfield (1994), Marsh (1954) and Marsh *et al.* (1987) and various others as most important factors controlling tenderisation. The management of the pH/temperature path to rigor mortis are used to determine if the carcass falls within an “abattoir window” of 12°C and 35°C at the point when pH reach 6.0 (Thompson *et al.*, 2006). Muscle entering rigor (pH=6) at too high (heat rigor and increased autolyses of proteolytic enzymes) or too low (cold shortening) temperatures is detrimental to tenderness and tenderness development.
- h) Carcass hanging method has an effect on eating quality of various muscles and depending on chiller conditions results in an improvement in palatability especially in extreme chilling conditions (too high or low rigor temperatures). When hanging carcasses by the aitch bone (obturator foramen: tender stretch) or other variations thereof instead of Achilles tendon, tenderness of the loin and certain muscles of the buttock is increased through stretching and inhibition of shortening during rigor mortis.
- i) *Post mortem* aging increase tenderness in general but the effect varies by muscle and is a function of connective tissue and fibre type (proteolytic enzymes) properties and post-slaughter conditions (Hwang & Thompson, 2001(b); Dransfield, 1994; Bouton & Harris, 1972; Shorthose & Harris, 1990).
- j) Cooking method (dry and moist heat) also affects different muscles differently is the final criteria for the system (Watson *et al.*, 2008(b)).



Description	Format	Name	Input
Estimated % <i>Bos indicus</i>	% or X if doubt	EPBI	25
Animal sex type	M / F	Sex	M
Hormone growth promotant	Yes or ? / No	HGP	N
Milk fed vealer	Yes / No	MFV	N
Saleyard	Yes / No	SIYrd	N
Rinse / Flush	Yes / No	RnFl	N
Hot std carcass weight	Weight in kg	HSCW	280
Hang method	AT/TS/TL/TC/TX	Hang	TS
Hump height	mm	Hump	5
Ossification USDA	USDA measure	uoss	120
Marbling USDA	USDA measure	umb	350
Rib fat	mm	RbFt	5
Ultimate pH	Metered Temp	UpH	5.5
Lion temp at grade		Utmp	3
Days of aging from kill	Days aged	Age	21

Cut	Muscle	GRL	RST	SFR	TSL	SCT	CRN
Spinals	SPN081	5	4	5	4		
Tenderloin	TDR034	5		4			
Tenderloin	TDR062	5	4	5	4		
Tenderloin	TDR063	4					
Cube roll	CUB045	4	4	4	4		
Striploin	STA045	4	4	4	4		
Striploin	STP045	4	4	4	4		
Oyster blade	OYS036	3	3	4	4		
Blade	BLD095						
Blade	BLD096	3	3	3	3	4	
Chucktender	CTR085		3	3	3	4	
Rump	RMP131	4	4	4	4	4	
Rump	RMP231	4	4	4	4	4	
Rump	RMP005	4		4	5		
Rump	RMP032			4	5		
Rump	RMP087		3	4	4	4	
Knuckle	KNU066	3	4	4	4	3	
Knuckle	KNU098		4	4	4	4	
Knuckle	KNU099	3	3	3	3	3	
Knuckle	KNU100		4	4	4	4	
Outside flat	OUT005		3	3	4	4	3
Outside flat	OUT029			3	4	3	
Eye round	EYE075	3	3	3	3	3	3
Topside	TOP001	3		3	4	3	
Topside	TOP033	3		3	4	4	
Topside	TOP073	3	3	3	4	4	
Chuck	CHK068			3	3	4	
Chuck	CHK074	4	3	3	4	4	
Chuck	CHK078	3	3	3	3	4	
Chuck	CHK081			3	4		
Chuck	CHK082			3	3		
Thin-flank	TFL051			3		3	
Thin-flank	TFL052			4	4		
Thin flank	TFL064			4	3	4	
Rib-blade	RIB041			3			
Brisket	BRI056				3	3	
Brisket	BBI057				3	4	
Shin	FQshin					4	
Shin	HQshin					4	
Intercostal	INT037			3			

Table 2 Example of Meat Standards Australia model output for a sample carcass (Cooking methods: GRL - grill, RST - roast, SFR - stir-fry, TSL - thin slice, SCT - slow cook and CRN – corned; Adopted from, Watson, *et al.* 2008b)

The grading model has evolved from a fixed parameter ‘Pathway’ approach, to a computer model that predicts consumer scores for 135 ‘cut by cooking method’ combinations for each graded carcass (Table 2).

The practical implications of the MSA Grading system in terms of recoding were described by Smith *et al.* (2008) and could be summarised as follows:

- MSA model data inputs from the supplier declaration are percentage *B. indicus*, HGP implant status, milk-fed veal ‘yes’ or ‘no’, and if from a sale yard.
- Inputs from the slaughter floor are carcass suspension method, whether a vascular infusion treatment has been applied, carcass weight (in kg) and sex.
- Inputs entered in the chiller from the quartered carcass are also defined under AUS-MEAT chiller assessment language and are identical to the AUS-MEAT language classification described above for rib fat, meat colour and fat colour. Of these, the model algorithm only uses rib fat for computation, meat and fat colour being censoring variables applied commercially to meet trace appearance standards.
- Additional MSA specific inputs are measured either on the slaughter floor or chiller: MSA marbling standard, maturity (or ossification), hump height, ultimate pH and the speed at which pH declines from the live state (~pH = 7.0) to the ultimate pH (pH 5.3 to 5.7 is optimal) combined with temperature



Measured against the criteria for a successful grading or classification scheme, viz. Accuracy, Simplicity, Ease of application, Cost, Measures against tampering, it probably only honours the first and last point. It is estimated that approximately 20-30% of the Australian beef kill is MSA graded. Indeed Australian research has shown that up to 50% of meat graded is miss-categorised when compared with consumers' assessments (Thompson, 2002). In summary, the MSA scheme is less about carcass description and more about Quality Assurance and conditions imposed in the abattoir.

What are the options for the SA industry?

There is no doubt that the MSA system would probably have the best outcome in terms of consumer satisfaction. It is in fact a palatability-assured-critical-control-point (PACCP) approach which is integrated into a grading system aimed at maximum consumer satisfaction for a number of cuts prepared according to different cooking methods. In this regard it differs from all other systems. It should be mentioned that certain adjustments will need to be made if the system is applied in other countries, e.g. marbling will have less emphasis in South Africa, while a beta agonist factor in the production system part would have to be included. However, considering our criteria for maximum uptake by all sectors of the industry, the system relies heavily on the integrity of the producer and a very well organised pre-harvest, harvest and post-harvest system with excellent traceability in place (referring to ease of application). For vertically integrated operations (feedlot, slaughterhouse and processing plant) these criteria may be in place but it could be argued that the criteria are already used (partly) by them and that classification (or grading) is not as essential to them as to the rest of the industry where every sector operates on its own and the product changes ownership at each point. In addition, the system is probably expensive (cost) and requires higher technical skills (simplicity) than the current system.

Conclusion

Considering any other system discussed in this document, none of them or even selected criteria adopted from them would significantly improve the SA system in our opinion. It is probably safe to conclude that the classification system at present probably distinguish between feedlot animals (mostly A-age, with 1-2% AB class animals and very few A age pasture animals), younger pasture animals (AB), older pasture animals (B) and cull animals (C). When the work of van Wyk *et al.* (2008), Frylinck *et al.* (2009) and Strydom *et al.* 2005 on the interaction between age and production system (nutrition), the work of Strydom *et al.* (2006) and others on electrical stimulation and the work of Strydom *et al.* (2010) and others on the beta agonists are considered, the preference for, and therefore price differential between, A and AB is unfounded if based on tenderness alone – in particular that of the loin (and other low connective tissue cuts). Although the definition of a classification system is that it “describes all of the scores or measurements” only and does not rank for quality and pricing purposes, the probability of experiencing a “bad steak” in the A class (feedlot) has probably increased since the implementation of the current system.

If existing documentation is taken into account we can conclude that the current measurements or scores are inadequate to define quality for different classes if tenderness is the most relevant quality aspect. However, the fact that the system indirectly distinguish (describe) between pasture and feedlot animals is very relevant when tenderness and other quality characteristics are considered, such as fat colour and flavour. Wood *et al.* (2003) and Campo *et al.* (2006) reported that the fatty acid composition of pasture and grain fed animals differ and that these differences relate to differences (not preferences) in taste (flavour, juiciness, aroma). Sañudo *et al.* (1998) described the significance of culinary cultural background on the acceptance meat coming from pasture or feedlots, thereby indicating preferences for flavour or taste based on experience. These studies emphasise the fact that the description (through classification) of two products that could be experienced differently by different consumers but without one-sided preference is probably the main objective of classification if variation in consumer preferences are expected. The fact of the matter is that even though a steak of an A, AB or B age carcass could have the same tenderness rating, the latter two differ in eating experience from the A carcass steak due to other qualities. In addition the appearance of two types of meat is different. Taking this into account a system more focussed on separating pasture and feedlot produced animals should be considered. Further development within these categories will then for feedlot animals consist of the utilisation or not (combination and type) of HGP's and beta agonists and will focus on tenderness outcomes. For pasture animals age would play a much more prominent role when tenderness of particularly the higher connective tissue cuts is considered, while additional characteristics such as fat and



meat colour could be scored as well. For both systems however, the variability caused by pre-harvest and harvest conditions still remains a challenge to be taken up in a classification system due to reasons mentioned before and tenderness variation especially for low connective tissue cuts can still not be captured easily by single or even easily applied multiple recordings and remains the biggest hurdle.

Finally, although it was speculated, with good support from the literature, that grain fed animals supplemented with a beta agonist will probably produce tougher meat (various cuts) than older pasture fed animals, this was never proven in SA. While all other scenarios of age interacting with production variable were tested locally, this should be regarded as an important research objective.

Acknowledgements

Me Elsabe Gagiano for her great effort in the technical preparation of this document.

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