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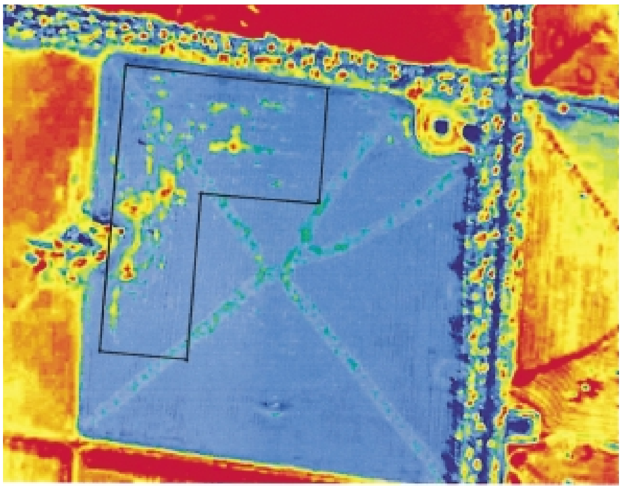

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The prediction of retail beef yield from real time ultrasound measurements on live animals at three stages through growout and finishing

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Abstract. Analyses were performed to test the relationship between retail beef yield percentage (RBY) and real time ultrasound measurements taken at weaning, entry to finishing and preslaughter for animals finished under pasture and feedlot conditions to meet domestic, Korean and Japanese market specifications.

The first analysis tested the power of live animal measurements (scanned P8 fat depth, scanned eye muscle area and liveweight) to predict RBY and contrasted this with a model containing these live animal measurements plus a term (HERD × KILL) which accounted for all known classification variables. This indicated that scanned P8 fat depth, measured at slaughter, was the most useful predictor of retail beef yield, accounting for 52% of the variation in RBY for the equation containing live animal measurements alone. The power of live animal measurements to predict RBY decreased as the time between scanning and slaughter increased. Models which included HERD × KILL predicted RBY accurately (accounting for 82–86% of the variation in RBY), but live animal measurements contributed little to this result, accounting for only 8% of the variation in RBY for measurements at slaughter in the presence of the HERD × KILL term.

A second analysis examined whether market category, finishing regime or breed classifications consistently influenced the relationship between the measured traits and RBY at the 3 scanning times. The magnitude of the variation between significantly different coefficients (for scanned P8 fat depth, scanned eye muscle area and liveweight) was generally small, though the results suggested that in some instances, developing separate equations for animals of different classifications would marginally improve the accuracy of RBY prediction.

The final analysis investigated the improvement in RBY prediction when measurements from entry to finishing were included with those taken before slaughter. HERD × KILL was included in the model to account for all known classification variables. Measurements of both P8 fat depth and EMA from the earlier measurement time were significant predictors of RBY in the presence of the corresponding measurement at slaughter, but accounted for an increase in R^2 of only 0.0007. It was concluded that a single scan and liveweight measurement, close to slaughter, would provide the best live animal measurements for RBY prediction, and that no improvement in accuracy would be achieved by additional scans taken earlier in an animal's life.

Introduction

Real time ultrasound scanning (RTUS) has become an established technique for measuring carcass traits in live beef cattle. The accuracy and repeatability of measurements obtained using modern scanning equipment has been extensively tested and documented. Wilson *et al*. (1995) reviewed reports of recent scanning accuracies and found consistently high correlations between RTUS fat depth and eye muscle area (EMA) and the corresponding carcass measurements (r = 0.75–0.96 for fat depth and 0.60–0.94 for eye muscle area).

The relationship between scanning measurements and retail beef yield has also been thoroughly examined. Bergen *et al.* (1996) examined the relationship between scanned rib fat and EMA with estimated carcass yield in 82 Angus and Charolais yearling bulls. Within these relatively homogenous groups, RTUS measurements accounted for 73% of the variation in estimated carcass yield. On a more heterogeneous group of 282 *Bos taurus*, *Bos indicus* and crossbred steers, Griener *et al*. (1995) showed that scanned rib fat depth was the most important determinant of carcass yield percentage in a model which also included muscle score, liveweight, scanned EMA, and accounted for 68% of the variation in carcass yield percentage. They also concluded that scanned measurements estimated carcass yield percentage as accurately as the same measurements

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taken on the carcass. A similar conclusion was also reached by Faulkner *et al*. (1990), Miller *et al*. (1988), Waldner *et al*. (1992) and Williams *et al*. (1997).

Few studies have examined scanning times other than pre-slaughter for prediction of carcass yield percentage. Hamlin *et al*. (1995) scanned animals 7 times during a 263-day feeding period. For pre-slaughter measurements regression equations containing scanned rib fat depth and EMA, and liveweight accounted for 61% of the variation in carcass yield percentage. There was a progressive loss in the predictive power of RTUS measurements as the time between scanning and slaughter increased, with measurements taken 200 days before slaughter accounting for only 36% of the variation in carcass yield percentage.

The design of the core project in the Cooperative Research Centre (CRC) for the Cattle and Beef Industry (Robinson 1995; Upton *et al*. 2001) provided an opportunity to examine the ability of RTUS measurements, taken at 3 times through the growth and finishing phases for 4 breeds, finished to 1 of 6 market × finishing treatments, to predict retail beef yield percentage. Preliminary examination of CRC scanning results (Wolcott *et al.* 1997), concluded that pre-slaughter RTUS measurements provided an accurate means of assessing retail beef yield percentage within finish × market categories, and that as the time between scanning and slaughter increased, the strength of this relationship decreased.

This study expanded on the work of Wolcott *et al.* (1997), and examined the ability of RTUS measurements at 3 scanning times to predict retail beef yield percentage (RBY). The contribution of all known classification variables to RBY prediction was examined and the value of live animal measurements in the presence of this information determined. The impact of different markets, finishing regimes and breeds on the relationships of scanning measurements and liveweight with RBY were then quantified to determine whether levels within these classifications significantly influenced prediction accuracy. Finally, the value of combining live animal measurements from more than one scanning time was examined to determine whether repeated measures improved RBY prediction accuracy.

Materials and methods

The cattle used in this experiment were part of the *Bos taurus* straight breeding project within the Beef Quality CRC. Progeny of 4 *Bos taurus* breeds [Angus (AA), Hereford (HH), Murray Grey (MG) and Shorthorn (SH)] were transported from co-operating breeders to CRC properties at, or shortly after, weaning. Upon arrival at the CRC properties, cattle were randomly allocated to 1 of 6 finishing × market treatments, which comprised feedlot or pasture finishing to domestic (400 kg), Korean (520 kg) or Japanese (600 kg) market liveweights. For more detailed information relating to the design of the CRC experiment see Robinson (1995).

Cattle were grown out on pasture until entering the finishing phase, at 300 kg (domestic) or 400 kg (Korean and Japanese). Animals were scanned on arrival at CRC properties, at entry to finishing, and within 1 week of slaughter. Scanning was carried out using an Aloka 500V real time ultrasound scanner with a 17 cm transducer. RTUS measurements of fat depth at the P8 site (P8) were recorded using the scanner's in-built callipers, and cross sectional images of the eye muscle (*M. longissimus thoracis et lumborum*) between the 12th and 13th ribs were recorded on video tape for later computer image analysis to determine EMA. Eye muscle images were digitised and EMA was determined (using a dedicated image analysis package) by tracing the boundaries of the muscle. The area within the identified muscle boundaries was then automatically calculated. A minimum of 3 images were measured for each animal, and the mean EMA calculated. All CRC animals were scanned by a single technician, accredited under the Performance Beef Breeders Association protocols (Upton *et al.* 1999).

Un-fasted liveweight was measured at each scanning time. The protocols set by the CRC required un-fasted weights be taken to minimise the impact on animal growth associated with fasting before fortnightly weighing. Smith *et al.* (1982) reported that only minimal improvement in the prediction of hot carcass weight from liveweight was achieved by extended fasting before weighing.

Of 1930 animals which were boned out under commercial abattoir conditions to measure carcass yield, scanning data were collected on 1579 head at slaughter, 1438 at entry to finishing and 1305 at weaning. Table 1 presents the number of observations, mean, standard deviation, minima and maxima for measurements analysed for this experiment within the 3 scanning times examined. The left sides of carcasses were processed to produce 17 primal cuts, manufacturing trim, fat and bone trim, as described by Perry *et al.* (2001). Retail beef yield percentage was calculated as the total weight of trimmed boneless retail cuts, plus the weight of adjusted lean manufacturing meat, expressed as a percentage of side weight. Hot carcass weight and carcass P8 fat depth were recorded. Carcass EMA measurements were not available for this analysis.

Statistical analyses

The ability of live animal measurements to predict RBY. The ability of models containing scanned P8 fat depth, EMA and liveweight to predict RBY was examined separately for each scanning time using the GLM procedure (SAS 1988). All first-order interactions between covariates were examined as descriptors of variation in RBY. All interactions were initially included in the model, and non-significant (P>0.05) interactions sequentially deleted. The interaction P8 fat depth × liveweight was significant (P<0.05) for all models, but contributed very little to the accuracy of RBY estimation (the R^2 increased by no more than 0.015 at any scanning time). Similarly, EMA × liveweight, measured at slaughter, was significant (P<0.05), but accounted for even less of the variance than the previous interaction. It was therefore decided to remove these interactions from the models due to their minimal contribution to prediction accuracy and to simplify the interpretation of the relationship between RTUS measurements, liveweight and RBY.

The ability of RTUS measurements and liveweight to predict RBY was corrected for possible influences of other fixed effects by including the HERD × KILL interaction effect in the model. HERD accounted for the effects of: herd of origin, breed, and any variation in environmental conditions associated with different locations of origin. KILL accounted for: the imposed treatments of market category and finishing regime, cohort (which defined the year/season in which animals entered the experiment), any nutritional treatments imposed on animals during the growout phase, the abattoir where the animals were slaughtered and their sex. Therefore the HERD × KILL term described hundreds of discrete classifications. The intercepts presented for these models were adjusted by the mean effect of the HERD × KILL interactions to provide a more accurate estimation.

A null model was also run with HERD × KILL as the only independent variable. This allowed the contributions of live animal measurements to

RBY prediction to be determined, after accounting for the variation in all factors described by the HERD × KILL term.

The influence of market category, finishing regime and breed on the relationship of RTUS measurements and liveweight with RBY. This analysis aimed to test the influence of the 3 market categories, 2 finishing regimes and 4 breeds on the relationship between live animal measurements and RBY. This was achieved by running 3 mixed models (PROC MIXED in SAS) for each scanning time. The first modelled P8 × market category, EMA × market category and liveweight × market category, with HERD × KILL included as a random variable. This was repeated for finishing regime and breed. For each covariate interaction term, significantly ($P<0.05$) different regression coefficients between levels within the market category, finishing regime and breed classes were interpreted as identifying cases where fixed effects influenced the relationship between covariates and RBY.

Multiple live animal measurements as predictors of RBY. A further analysis investigated the improvement in RBY prediction when information from more than one scanning time was included in the equation. The model included live animal measurements (scanned P8 fat depth, scanned EMA, liveweight at scanning) from both entry to finishing and slaughter (it was assumed that the inclusion of weaning measurements would contribute little to RBY prediction), and included HERD × KILL to account for the effect of all classification variables. Non-significant ($P>0.05$) covariates were sequentially dropped from the model. To allow the direct comparison of R^2 values between models, this analysis used a reduced data set, which contained only results from animals that had measurements from both entry to finishing and slaughter scanning times ($n = 1225$).

Results and discussion

The ability of live animal measurements to predict RBY

The correlation between scanned P8 fat depth measured by RTUS at slaughter and the corresponding carcass measurement was 0.81. This was similar to results presented by Bergen *et al*. (1996) and Smith *et al.* (1992) who reported correlations of 0.84 and 0.81, respectively. Liveweight (measured on un-fasted animals in the week before slaughter) had a correlation of 0.97 with hot carcass weight, which was slightly higher than that reported by Smith *et al.* (1982) who contrasted the relationship between hot carcass weight and liveweights measured on both a fasted and un-fasted basis.

Table 2 presents regression equations to predict RBY from live animal measurements taken at each of the 3 scanning times. For each scanning time models are presented which include terms for scanned P8 fat depth, EMA and LW before and after adjustment for HERD × KILL. When scanning was carried out at slaughter, live animal measurements alone accounted for 56% of the variation observed in RBY. This decreased to 38 and 6% for measurements at entry to finishing and weaning, respectively. Of the live animal measurements, scanned P8 fat depth was consistently the most powerful predictor of RBY, with partial R^2 values explaining 55, 25 and 5% of the variation in RBY at slaughter, entry to finishing and weaning, respectively. This agreed with the results by Griener *et al*. (1995), where a single measure of fat depth at slaughter accounted for 57% of the variation in RBY, and supports the conclusions of previous analyses of Beef Quality CRC data (Wolcott *et al*. 1997) that the best prediction of RBY was achieved from live animal measurements taken closest to slaughter. The regression coefficients for the 3 live animal measurements across scanning times indicated that increased fatness and liveweight resulted in decreased RBY, while increased EMA was related to higher RBY, when corrected for other terms in the model.

Table 1. Number of observations, means (± s.d.), minima and maxima for live animal measurements and percentage retail beef yield at three scanning times

Since results for retail beef yield from different numbers were analysed for each scanning time, the descriptive statistics for this trait differ slightly at slaughter, entry to finishing and weaning

Trait	No. of obs.	Mean ± s.d.	Minima	Maxima
		Scanned P8 fat depth (mm)		
Weaning	1305	2.8 ± 1.6	1.0	11.0
Entry to finishing	1438	4.5 ± 2.7	1.0	20.0
Preslaughter	1579	10.7 ± 4.6	1.0	32.0
		Scanned eye muscle area (cm^2)		
Weaning	1305	41.3 ± 8.2	20.0	67.0
Entry to finishing	1438	50.1 ± 7.7	31.0	84.0
Preslaughter	1579	63.5 ± 10.4	33.0	102.0
		Un-fasted liveweight (kg)		
Weaning	1305	267.4 ± 49.2	120.0	413.0
Entry to finishing	1438	355.7 ± 60.1	184.0	532.0
Preslaughter	1579	490.0 ± 88.0	250.0	792.0
		Retail beef yield (%)		
Weaning	1305	66.9 ± 3.7	55.0	77.0
Entry to finishing	1438	66.7 ± 3.7	54.0	75.9
Preslaughter	1579	67.2 ± 3.8	54.0	77.2

Although entry to finishing was analysed as a single event there was actually a 100 kg difference in liveweight (with corresponding differences in fat depth and muscling) between animals being finished for the domestic and export (Japanese and Korean) markets. This variation was reflected in the coefficients for liveweight and EMA which were of substantially greater magnitude at entry to finishing than was the case at other scanning times. By fitting HERD × KILL in the model, market category was accounted for and the magnitude of coefficients for covariates at entry to finishing more closely reflects those reported for slaughter measurements.

After HERD × KILL was included in the model, live animal measurements (as demonstrated by comparison with the R^2 and r.s.d. for the model containing HERD × KILL alone) contributed little additional information to RBY prediction. At no scanning time did the inclusion of fat depth, EMA and liveweight measurements increase R^2 by more than 8% (or decrease r.s.d. by more than 0.3). This suggested that when animals could be described as thoroughly as was the case in the Beef Quality CRCs core project (i.e. in terms of market category, finishing regime, breed and all other factors described by the HERD × KILL term), the value of scanning to predict RBY may be marginal.

Influence of market category, finishing regime and breed on RBY prediction

Table 3 presents the significant (P<0.05) regression coefficients for live animal measurements, modelled as their interaction with the fixed effects of market category, finishing regime and breed, at each scanning time. The effect of the remaining classification variables was accounted for by running HERD × KILL as a random variable. The influence of the market category, finishing regime and breed is discussed separately for each of the covariates.

P8 fat depth

Neither market category nor finishing regime affected the slope of the relationship between scanned P8 fat depth and RBY, at any scanning time. This means that regardless of the target liveweight (market category) to which animals were finished, or whether finishing occurred on pasture or in the feedlot, a change in scanned P8 fat depth had a consistent relationship with RBY.

Significant differences existed between the regression coefficients for P8 fat depth between breeds for scanning measurements taken before slaughter and at weaning. At slaughter, the effect of a change in P8 fat depth had a greater impact on RBY for Angus and Murray Grey animals than was the case for Herefords and Shorthorns, which most likely reflect differences in fat distribution and partitioning between the breeds. Research by Kempster *et al*. (1976) supports the conclusion that animals of different breeds display different fat distribution patterns, which are not described by measurements of fat depth at only 1 site.

Eye muscle area

Market category affected the relationship between EMA and RBY only for pre-slaughter measurements. For measurements at slaughter, an increase in EMA had a smaller influence on the RBY of Japanese carcasses, than was the case for the domestic market category carcasses. Obtaining high quality ultrasound images of the eye muscle in larger, fatter Japanese animals is difficult, and consequently this may simply reflect the lower measurement accuracy in fat animals.

At entry to finishing, significant differences existed between the EMA coefficients for animals finished under feedlot or pasture conditions. Feedlot animals displayed a

Table 2. Regression coefficients (*b*), standard errors (s.e.), coefficients of determination (R^2) and residual standard deviations (r.s.d.) for models to predict percentage retail beef yield (RBY) from scanned P8 fat depth (P8), scanned eye muscle area (EMA) and liveweight (LW) measurements alone, and after accounting for all recorded fixed effects (HERD × KILL)

R^2 and r.s.d. for a model containing fixed effects only (HERD × KILL) are also presented

Model	Intercept	P8 fat depth		Eye muscle area		Liveweight		R^2	r.s.d.
		b	s.e.	*b*	s.e.	*b*	s.e.		
				Pre-slaughter					
P8 + EMA + LW	74.58	–0.523	0.019	0.075	0.009	–0.013	0.001	0.56	2.49
P8 + EMA + LW + HERD × KILL	70.87	–0.377	0.019	0.054	0.008	–0.006	0.001	0.87	1.65
				Entry to finish					
P8 + EMA + LW	69.08	–0.650	0.041	0.208	0.014	–0.278	0.002	0.38	2.91
P8 + EMA + LW + HERD × KILL	67.95	–0.520	0.037	0.087	0.013	–0.009	0.002	0.82	1.77
				Weaning					
P8 + EMA + LW	68.18	–0.523	0.081	0.055	0.020	–0.008	0.004	0.06	3.62
P8 + EMA + LW + HERD × KILL	66.76	–0.601	0.051	0.078	0.015	–0.005[A]	0.002[A]	0.82	1.78
HERD × KILL only								0.78	1.95

[A]Regression coefficients are not significantly different from zero.

greater increase in RBY due to a unit increase in EMA than was the case for their pasture-finished contemporaries. This suggests that the different feeding treatments imposed during finishing may have influenced tissue deposition and fat partitioning. At entry to finishing, a change in the EMA of feedlot animals had a greater influence on RBY than was the case for pasture-finished animals.

For measurements taken at slaughter and entry to finishing, there was no difference in the relationship between a unit increase in EMA and RBY between breeds. At weaning, however, a unit increase in EMA produced a larger increase in RBY for Murray Grey animals than for Shorthorns. That differences between breeds were significant at weaning but were not at later scanning times was interpreted as reflecting a greater importance of EMA in describing RBY in animals that had not yet laid down sufficient fat to identify differences in RBY at slaughter.

Liveweight

Within market categories there were no significant differences between coefficients for liveweight when measured at slaughter. The RBY of export animals decreased more for an increase in liveweight at earlier scanning times, than was the case for domestic animals.

Finish was the only fixed effect examined that significantly affected the relationship between RBY and liveweight at all scanning times. A unit increase in liveweight consistently reduced the RBY of feedlot animals more than the RBY of their pasture-finished contemporaries. It is likely that differences in liveweight were accounting for variation in fatness that was not being partitioned to the coefficient associated with P8 fat depth. This may, again, point to a difference in fat distribution and highlight the limitations of a single point measure of subcutaneous fatness to account for all of the variation in total carcass fatness.

Table 3. Significant (P<0.05) regression coefficients (calculated within scanning times) for the prediction of percentage retail beef yield from equations containing P8 fat depth, eye muscle area and liveweight modelled as their interaction with the fixed effects of market category, finishing regime and breed

EMA, eye muscle area; LW, liveweight; *b*, regression coefficient; s.e., standard error of estimate. Coefficients followed by different letters are significantly different at P = 0.05; non-significant terms are not presented

	Preslaughter		Entry to finishing		Weaning	
	b	s.e.	*b*	s.e.	*b*	s.e.
Breed × P8 fat depth						
Angus	–0.456a	0.023			–0.598a	0.065
Hereford	–0.341b	0.035			–0.615a	0.122
Murray Grey	–0.577a	0.051			–0.800a	0.159
Shorthorn	–0.306b	0.052			–0.396b	0.126
Market × EMA						
Domestic	0.080b	0.013				
Korean	0.053ab	0.011				
Japanese	0.030a	0.015				
Finish × EMA						
Feedlot			0.137a	0.015		
Pasture			0.086b	0.017		
Breed × EMA						
Angus					0.054ab	0.020
Hereford					0.098ab	0.027
Murray Grey					0.168a	0.042
Shorthorn					0.036b	0.038
Market × LW						
Domestic			–0.003b	0.003	–0.002b	0.003
Korean			–0.012a	0.002	–0.015a	0.004
Japanese			–0.016a	0.003	–0.012a	0.005
Finish × LW						
Feedlot	–0.013b	0.001	–0.022a	0.002	–0.010a	0.003
Pasture	–0.008a	0.002	–0.007b	0.002	–0.001b	0.004
Breed × LW						
Angus	–0.009a	0.001				
Hereford	–0.012ab	0.002				
Murray Grey	–0.011ab	0.003				
Shorthorn	–0.018b	0.003				

Table 4. Significant regression coefficients for covariates (corrected for all classification variables) in models to predict percentage retail beef yield (RBY), when live animal measurements from entry to finishing and slaughter were included in the model

P8, scanned P8 fat depth; EMA, scanned eye muscle area; LW, un-fasted liveweight

Covariate	Preslaughter data only		Preslaughter + entry to finishing	
	Coefficient	s.e.	Coefficient	s.e.
n	1225		1225	
P8: pre-slaughter (mm)	–0.376	0.025	–0.281	0.025
Entry to finishing (mm)			–0.281	0.042
EMA: pre-slaughter (cm^2)	0.053	0.011	0.034	0.010
Entry to finishing (cm^2)			0.059	0.013
LW: pre-slaughter (kg)	–0.007	0.002	–0.008	0.001
Entry to finishing (kg)			n.s.	
R^2 (r.s.d.)	0.858 (1.64)		0.865 (1.60)	

An increase in liveweight had significantly different effects on RBY for different breeds when measured at slaughter, but this was not the case when liveweight was measured at entry to finishing and weaning. At slaughter a unit increase in liveweight had a more negative influence on RBY for Shorthorn animals than was the case for the other breeds examined.

These results indicated that an improvement in RBY prediction accuracy could be achieved by developing market, finish and breed specific equations. The magnitude of the variation between significantly different coefficients was generally small, however, and the actual improvement in prediction accuracy achieved through breed, market or finish specific equations may be small.

Multiple live animal measures to predict RBY

When live animal measurements taken at entry to finishing were included with those from slaughter (Table 4), P8 fat depths and EMA measurements from both scanning times were significant predictors of RBY (P<0.05). Liveweight at entry to finishing was not a significant term in the presence of weight measured at slaughter. The inclusion of measurements from entry to finishing increased R^2 by only 0.0007 when compared with a model containing slaughter measurements alone. These results suggest that, in the presence of HERD × KILL, live animal measurements recorded at entry to finishing contributed little to RBY prediction, when slaughter measurements were available.

Conclusions

This experiment indicated that the ability of live animal measurements, taken at slaughter, to predict RBY was not significantly improved by adding results from measurements performed earlier in an animal's life. Of the measurements tested, only P8 fat depth, measured before slaughter, had a strong relationship with RBY, accounting for 55% of the variation in RBY in an equation containing live animal measurements alone. A null model, containing HERD × KILL alone, accounted for 78% of the variation in RBY. By including live animal measurements, an additional 8% of the variation in RBY was accounted for, producing a model with an R^2 of 0.87.

Significant differences were found to exist in the relationship between live animal measurements and RBY when modelled within market category, finishing regime and breed classifications. This result suggested that equations specific to animals of different breeds, finished under different nutritional regimes and to different market specifications could improve RBY prediction accuracy.

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