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# Genetic evaluation for length of productive life in Slovak Pinzgau cattle

## Abstract
The proportional hazards method was used to estimate breeding values for functional length of productive life within the endangered Slovak Pinzgau population. The analyzed data set contained 21,985 cows, daughters of 254 sires. The risk of culling was higher for cows with lower milk production relative to herd average, higher age at first calving and in herds decreasing in size. In the first lactation the culling risk was highest at the beginning, and decreased during lactation. From second lactation onwards an increasing risk was observed. The effect of breed composition was found insignificant, and was not included into final model. A heritability of 0.05 was estimated for functional length of productive life. The average reliability of estimates was 0.25. No clear tendency in average breeding values by year of birth of bulls was observed.

Keywords: Pinzgau cattle, functional longevity, proportional hazards model, heritability, breeding value

## Zusammenfassung
Titel der Arbeit: **Zuchtwertschätzung für die Nutzungsdauer beim Slowakischen Pinzgauer Rind**
Für die in der Slowakei als gefährdet eingestufte Rinderrasse Pinzgauer wurde eine Zuchtwertschätzung für funktionale Nutzungsdauer auf Basis des propotionalen Ausfallmodells entwickelt. Der analysierte Datensatz umfasste 21.985 Herdebuchkühe mit 254 verschiedenen Vätern. Das Abgangsrisiko war höher für Kühe mit im Vergleich zum Herdendurchschnitt unterdurchschnittlicher relativer Milchleistung, für Kühe mit höherem Erstkalbealter und für Kühe in Herden mit sinkender Herdengröße. In der ersten Laktation war das Abgangsrisiko am Beginn der Laktation am höchsten und sank während der Laktation ab. Ab der zweiten Laktation stieg das Merzungsrisiko hingegen während der Laktation an. Der Einfluss des Fremdgenanteils war in Voranalysen nicht signifikant und wurde folglich nicht im Modell berücksichtigt. Für das Merkmal funktionale Nutzungsdauer wurde eine Heritabilität von 0,05 geschätzt. Die durchschnittliche Sicherheit der Zuchtwerte der Stiere betrug 0,25. Für die Stiere war keine klare Tendenz hinsichtlich der durchschnittlichen Zuchtwerte pro Geburtsjahr zu erkennen.

Schlüsselwörter: Pinzgauer Rind, funktionale Nutzungsdauer, proportionales Ausfallmodell, Heritabilität, Zuchtwert

## Introduction
The length of productive life in cattle is the time period between first calving and culling. According to MIESENBERGER (1997) it accounts for 22.3 % of the overall economic value in the total merit index in Austrian Pinzgau cattle, which covers the majority of the 45 % relative economic importance of functional traits assessed by SÖLKNER et al. (2000). Its high economic value was also pointed out in a review of ESSL (1998), and further confirmed in breeding conditions of Slovakia and Czech Republic by KRUPA et al. (2006) and WOLFOVÁ et al. (2007), respectively. SWALVE (2003) emphasized the importance of longevity and called it as a “natural

index" combining other functional traits. The main effect of prolonged production life is the increase of overall profitability of milk production by reduced replacement costs and an increased proportion of mature, high producing cows. The trait of particular interest for the breeder is functional longevity, which is independent of production and reflects the fertility, health, and overall fitness of the cow (VUKASINOVIC et al., 2001; DÁKAY et al., 2006). The word "functional" denotes length of production life corrected for milk production. The most common approach, first time used by DUCROCQ (1987), is to compare production of a cow to the mean production within herd.
Longevity is officially evaluated in 20 of the 42 Interbull member states (Interbull, November 2007). In the neighboring countries of Slovakia, breeding values for longevity are estimated in Austria (FUERST and EGGER-DANNER, 2002) and Hungary (LINDE et al., 2006). The preparation for routine evaluation in Czech Republic was carried out by PÁCHOVÁ et al. (2005). The longevity of cattle populations in Poland and Ukraine has not yet been officially evaluated.
The size of the purebred Pinzgau population was permanently decreasing due to the utilization of Holstein sires (MÉSZÁROS et al., 2008) as well as the low number of purebred Pinzgau sires available for reproduction. For these reasons the Pinzgau breed is considered to be endangered. These tendencies negatively influenced development of intensity of inbreeding in the population. Depending on breeding program the expected increase of inbreeding ranges from 0.25 to 2.18 % per generation (KADLEČÍK et al., 2004). In the purebred, active population the average inbreeding coefficient was $F_{\bar{x}} = 0.0011 \pm 0.0123$ (KADLEČÍK, unpublished). KASARDA and KADLEČÍK (2007) observed an inbreeding depression in EBVs of −8.95 kg milk, −0.37 kg fat and −0.36 kg protein per 1 % of inbreeding, respectively. Additional costs of inbreeding could arise from early embryothic death, losses in calves and heifers, lower growth rates and infertility (FREYER et al., 2005).
To stop these negative tendencies in the development of the Slovak Pinzgau population, international cooperation is needed. The Pinzgau populations of Slovakia and Austria are genetically well connected. The possibility of a joint breeding value estimation with Austria, Germany and Slovakia was outlined by EGGER-DANNER et al. (2005).
The aim of this study was to analyze effects affecting length of productive life, including estimation of heritability and evaluation of breeding values for functional length of productive life in the Slovak Pinzgau population.

## Materials and methods

A data set of 21,985 Slovak Pinzgau cows born from 1995 to 2004 was analyzed. The reason of this restriction was an incomplete database of older cows, which could potentially lead to an upward bias in evaluation of length of productive life. Cows with an age at first calving less than 18 or more than 51 months, with a missing date of calving or originating from herds with less than 20 animals were deleted. The total number of herds was 145. The minimum number of daughters per sire was 8 with a total number of sires of 254. Cows alive at the time of data collection or removed from milk recording by the decision of the breeder were right censored, i.e. their lifespan is assumed to be longer than observed. The time of censoring was the date of the end of the last known lactation. Cows alive at the beginning of the seventh lactation were censored at the end of the sixth lactation, because of the low number of animals in these higher lactations. A total of 6,824 cows (31.04%) were treated as censored.

The analysis was carried out using a proportional hazards model, assumed to follow the Weibull distribution (The Survival Kit 3.12, DUCROCQ and SÖLKNER, 1998):

$$\lambda(t) = \lambda_0(t) \exp (hy_i + rp_j + ps_k + hs_l + afc_m + s_n)$$

where: $\lambda(t)$ = the hazard function of an animal at time t; $\lambda_0(t)$ = Weibull baseline hazard function; $hy_i$ = random time dependent effect of herd × year of calving; $rp_j$ = fixed time dependent effect of relative milk production; $ps_k$ = fixed time dependent effect of parity × stage of lactation; $hs_l$ = fixed time dependent effect of annual herd size change; $afc_m$ = fixed time independent effect of age at first calving; $s_n$ = random time independent effect of sire.

The risk of culling was expressed by risk ratios, which denoted the relative risk of a cow in a certain class to be culled, compared to a cow in a reference class, with risk ratio (RR) set to 1.

The correction for within herd milk production was performed in several steps. First the amount of milk production in case of incomplete lactations (less than 240 days) was extended to 305 days, using the Wood curve (WOOD, 1967):

$$Y_t = at^b e^{-ct}$$

where: $Y_t$ = the milk yield at day $t$ of lactation; the parameters $b$ and $c$ are associated with the shape of the lactation curve of Austrian Pinzgau cattle, for which test day yields and average curves were available for each lactation, the scaling factor (parameter $a$) was estimated for the evaluated dataset. Lactations longer than 240 days were not extended, as these are considered as full lactations in Slovakia. In a second step, all lactations from higher parities were corrected to the level of first lactation, using factors of 1.19 to 1.33 depending on the number of lactation. Relative milk production was then expressed as deviation from the herd mean. In the final step the relative milk production was assigned into one of the nine classes, according to their difference from the herd mean defined by standard deviations (Table 1).

The time dependent effects of stage of lactation and parity were considered jointly. The first lactation was divided into two stages to estimate the risk in its first and the second half, split at day 180. Three stages of lactation were considered from the second lactation onwards to evaluate the risk of culling at the beginning (days 1-60), mid (days 61-180) and late (days > 180) lactation.

Cows were split into seven groups according to their age at first calving. To avoid unbalanced numbers of animals in the extreme classes, their bounds were set to contain 10% of the data. All other cows were divided into five intervals of approximately 3 months each.

Change in herd size was expressed as deviation from the herd size in the previous year, and it was assumed to change at 1st of January every year. Only herds with an overall number of more than 20 cows were included. Cows from herds with more

than 50% decrease in size in one year were considered as right censored, following the approach of DUCROCQ (1999).
Only cows with 50% or more Pinzgau genes were included in the analysis. In the original model the effect of breed composition was also considered as the proportion of Pinzgau genes (percentages of 50-75, 75.1-87.5, 87.51-93.75 and >93.75). This effect was not significant however, and was discarded from the final model.
For the estimation of heritability the equation by YAZDI et al. (2002) was used:

$$h^2=4\,\sigma_s^2/[\sigma_s^2+(1/p)] \quad (1)$$

where: $h^2$ = the coefficient of heritability for functional length of productive life, $\sigma_s^2$ = the genetic variance of sires, $p$ = the proportion of uncensored records.
Breeding values for functional length of productive life were computed using these parameter estimates. Average breeding values were calculated compared to the mean and standard deviation of the group of base sires, with year of birth between 1995 and 1999. Equation (2) was used for breeding value computation.

$$BV = \{[(est-a)/sd] \cdot (-12)\} + 100 \quad (2)$$

where: $BV$ = the breeding value of a bull, $est$ = the estimate for a bull, $a$ = the mean of estimates in the group of base sires, $sd$ = the standard deviation of estimates of base sires. The minus sign represents the alternation of breeding values, in order to express prolonged production life of daughters of the bull with higher breeding value.
Reliability was computed according to DUCROCQ (1999):

$$R = n/\{n+[(4-h^2)/h^2]\} \quad (3)$$

where: $R$ = the value of the reliability, $n$ = the number of uncensored daughters of a sire, $h^2$ = the estimated heritability of functional length of productive life.

## Results

Average age at first calving was 36 months. Length of productive life was 2.4 years in the whole evaluated dataset, 2.3 and 2.8 years for the uncensored and censored cows, respectively.
The risk ratios for relative milk production are shown in Table 1. The risk of culling was highest for cows with the lowest amount of milk production compared to the herd mean, and it continuously decreased with increasing relative milk production. Cows with milk yield 1.5 standard deviations below the herd mean were 5.3 times more likely to be culled than cows with average production. On the other hand, cows with extremely high yield (more than 1.5 standard deviations relative to the herd mean) showed an approximately 2.4 times lower risk to be culled compared to an average cow.

Table 1
Estimates of risk ratios for classes of the relative milk production
(Schätzwerte für das Ausfallsrisiko in den Klassen der relativen Milchleistung)

| Class | Lower bound of lactation value (sd) | Upper bound of lactation value (sd) | Risk ratio |
|---|---|---|---|
| 1 | | <−1.5 | 5.275 |
| 2 | −1.5 | <−1.0 | 2.404 |
| 3 | −1.0 | <−0.5 | 1.637 |
| 4 | −0.5 | <−0.2 | 1.236 |
| 5 | −0.2 | <+0.2 | 1.000 |
| 6 | +0.2 | <+0.5 | 0.791 |
| 7 | +0.5 | <+1.0 | 0.686 |
| 8 | +1.0 | +1.5 | 0.552 |
| 9 | >+1.5 | | 0.421 |

sd = standard deviation

For the combined effect of parity × stage of lactation, the risk of culling for each class is shown in Table 2. The risk of culling decreased during the first, and increased during the later lactations. It was the highest for the first half of the first lactation, with a risk ratio more than 4 times higher compared to the second half.

Table 2
Estimates of risk ratios for classes of the combined factor parity × stage of lactation
(Schätzwerte für das Ausfallsrisiko in den Klassen des kombinierten Effektes Laktation × Laktationsstadium)

| Lactation | Stage of lactation (bounds in days in milk) 1 (to 60 d) | 2 (61 to 180 d) | 3 (above 180 d) |
|---|---|---|---|
| 1 | | 4.149[a] | 1.000 |
| 2 | 0.320 | 0.402 | 0.394 |
| 3 | 0.162 | 0.195 | 0.261 |
| 4 | 0.116 | 0.149 | 0.212 |
| 5 | 0.112 | 0.141 | 0.228 |
| 6 | 0.112 | 0.174 | 0.378 |

a = from 1 to 180 days

A higher risk of culling was found for cows in herds decreasing in size, as shown in Table 3. Cows from herds decreasing their size by 20 to 50% were 2 times more likely to be culled than cows in herds of stable size. Cows from herds increasing in size were less prone to culling. The risk of culling was approximately 2 times lower compared to stable herds.

Table 3
Estimates of risk ratios for classes of the relative change of the herd size (Schätzwerte für das Ausfallsrisiko in den Klassen der Änderung der Herdengröße)

| Class | Lower bound for relative change in herd size | Upper bound for relative change in herd size | Risk ratio |
|---|---|---|---|
| 1 | −50% | <−20% | 2.050 |
| 2 | −20% | <+20% | 1.000 |
| 3 | +20% | <+50% | 0.723 |
| 4 | +50% | | 0.467 |

Age at first calving had less effect on risk of culling. As shown in Table 4, the risk of culling was the lowest for the class with age at first calving approximately from 34 to 37 months of age. Cows having calved for the first time at lower ages had a slightly higher risk of culling, more noticeable for the youngest cows. The risk of culling increased for later calvers. The highest risk was observed for cows having calved older than 43 months.

Table 4
Estimates of risk ratios for classes of age at first calving
(Schätzwerte für das Ausfallsrisiko in den Klassen des Erstkalbealters)

| Class | Lower bound for age at first calving | Upper bound for age at first calving | Risk ratio |
|---|---|---|---|
| 1 | | 847 d | 1.053 |
| 2 | 848 d | 934 d | 1.014 |
| 3 | 935 d | 1,021 d | 1.001 |
| 4 | 1,022 d | 1,108 d | 1.000 |
| 5 | 1,109 d | 1,195 d | 1.084 |
| 6 | 1,196 d | 1,282 d | 1.178 |
| 7 | 1,283 d | | 1.195 |

A heritability of $h^2 = 0.05$ was estimated for the functional length of productive life using equation (1). The breeding values were calculated for sires of the cows using equation (2). The breeding value of 100 meant an average risk to be culled for a daughter of a particular sire; breeding values of bulls ranged from 66 to 140. The average breeding values of bulls by year of birth are presented in Figure 1. The minimum number of sires born in a year was 5.

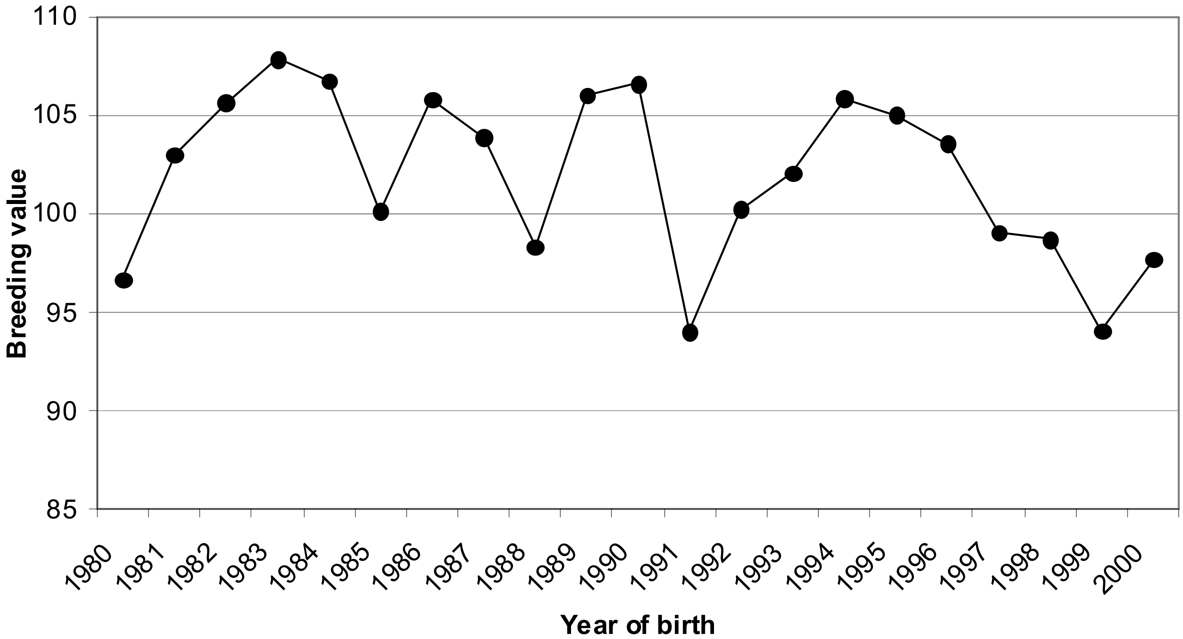


Fig. 1: Average breeding values by sires year of birth
(Durchschnittliche Zuchtwerte nach Bullen-Geburtsjahrgängen)

Reliability of breeding values was calculated according to DUCROCQ (1999), with a mean of 0.25 and a standard deviation of 0.21, the maximum value was 0.96. The average reliability was achieved from bulls with 27 uncensored daughters. To achieve a reliability of 30%, 34 uncensored daughters were needed. For reliabilities of 50, 60, 70 and 80% 79, 119, 184 and 315 uncensored daughters were needed, respectively.

## Discussion

All effects in our model significantly affected the length of productive life, relative milk production was found to be the most important. There was a general agreement among authors of similar studies that risk of culling is decreasing with increasing milk production of cows (FUERST and EGGER-DANNER, 2002; OJANGO et al., 2005; PÁCHOVÁ et al., 2005; BIELFELDT et al. 2006; MÉSZÁROS et al., 2008). In most of cases (FUERST and EGGER-DANNER, 2002; EGGER-DANNER et al., 2005; PÁCHOVÁ et al., 2005; CHIRINOS et al., 2007) the risk of culling was significantly higher for cows with lower milk production relative to herd mean. DÜRR et al. (1999) and PÁCHOVÁ et al. (2005) stated 4.9 and 5 times higher risk for cows producing 1.5 standard deviation under the herds average, MÉSZÁROS et al. (2008) found 4.8 times higher risk in the same class. These results are in agreement with the current finding of 5.2 times higher risk for the lowest producing cows. EGGER-DANNER et al. (2005) found two times higher risk of culling for cows producing about one standard deviation less, than the average production in the herd, which is also comparable with the present results of 1.6 and 2.4 times greater chance to be culled for cows from class 2 and 3 (see Table 1). The risk ratios were much higher for cows from classes with low milk yield compared those producing more than the herds average in analyses of BIELFELDT et al. (2006) and CHIRINOS et al. (2007). Some studies investigated the effects of fat and protein content. The trend was similar, but the risk of culling is lower compared to milk production (FUERST and EGGER-DANNER, 2002; EGGER-DANNER et al., 2005; CHIRINOS et al., 2007).

The definition of time intervals for stages of lactation is slightly different in separate studies. Mostly three (SEWALEM et al., 2005; EGGER-DANNER et al., 2005; BIELFELDT et al., 2006) or four stages (VOLLEMA et al., 2000; PÁCHOVÁ et al., 2005; MÉSZÁROS et al., 2008) were used to define the differences between early and late lactations, according to parity. ROXTRÖM and STRANDBERG (2002) used five, LINDE et al. (2006) seven stages in each lactation. The most common result for the combined effect of parity × stage of lactation was a decrease of risk during the first, and an increase during further lactations, with a decrease over lactations. An increase of risk over the lactations was observed by LINDE et al. (2006) and CHIRINOS et al. (2007).

In the present study lactations were divided into three stages with changes at 60 and 180 days. The first two stages of first lactation were merged to evaluate the risk of culling in the first half of the first lactation. Farmers tend to get rid of very low producing cows, or of those with low reproductive performance. These voluntary or involuntary culling decisions are usually made in the first half of the first lactation, to prevent expenses. The highest risk to be culled was observed in the first stage of first lactation, expressed by risk ratio of 5.2. A different pattern of risk ratio was observed from second lactations onwards, with increasing risk during, and decreasing between lactations. The high risk of culling in the third stage of sixth lactation was probably caused by relatively low number of observations compared to other classes. The present results are in agreement with those of PÁCHOVÁ et al. (2005), EGGER-DANNER et al. (2005), DUCROCQ (1999), VUKASINOVIC et al. (2001) and BIELFELDT et al. (2006) who found an increasing risk of culling in all lactations, and also between lactations. An increased risk of culling during the first

stage of first lactation was found by VUKASINOVIC et al. (2001), which was explained by different selection criteria in first lactating cows.
The effect of herd size change is usually the difference in total number of cows per herd expressed in percentages between subsequent years. In most cases (VOLLEMA et al., 2000; FUERST and EGGER-DANNER, 2002; EGGER-DANNER et al., 2005) the risk ratio was higher for cows in herds decreasing, and lower for cows in herds increasing in size. Surprising results were presented by DÜRR et al. (1999), when both cows from herds increasing or decreasing their size had an increased risk of culling, compared to cows in stable herds. CHIRINOS et al. (2007) found higher risk to be culled just for herds decreasing their size by 20% or more in one year, while no effect on the risk of culling was observed for slightly decreasing or increasing the herd size.
The marginal values of classes of herd size change were similar to those of FUERST and EGGER-DANNER (2002) and EGGER-DANNER et al. (2005) with five classes with average class between ±15% compared to ±20% used in the present study. The average class was more tightly defined by DUCROCQ (1994), DÜRR et al. (1999) with ±5% and by VOLLEMA (2000) with ±10% of annual herd size change. The extreme classes were defined differently in various analyses ranging from ±15% (DUCROCQ, 1994) to ±50% (FUERST and EGGER-DANNER, 2002; EGGER-DANNER et al., 2005; MÉSZÁROS et al., 2008).
Regardless of the bounds used to define the respective classes, there was a general agreement of lower risk to be culled for cows from expanding, and higher risk for cows from decreasing herds, which was in agreement with the present results. The risk ratio for decreasing herds from 20 to 50% (RR=2.05) was slightly higher compared to analyses of VOLLEMA et al. (2000), EGGER-DANNER et al. (2005) close to RR=1.2. The differences were even higher in case of the expanding herds, when the present results showed 2.5 times lower risk to be culled for animals from herds expanding their size with more than 50% compared to only 1.25 times lower risk in VOLLEMA et al. (2000) and EGGER-DANNER et al. (2005).
Similarly to the results of other authors (VUKASINOVIC et al., 2001; SEWALEM et al., 2005; PÁCHOVÁ et al., 2005; BIELFELDT et al., 2006; CHIRINOS et al., 2007) the age at first calving significantly affected the length of productive life, but the differences between classes were small. The risk of culling by age at first calving was nearly unchanged till 34 to 37 months (class 5 in Table 4). The risk ratio increased to a maximum of 1.195 for cows calving the first time later than 42 months of age, which corresponds with results of EGGER-DANNER et al. (2005), who observed a risk ratio of 1.2 for cows first time calved in 44 months of age. The relatively high age at first calving at Pinzgau cattle could be the consequence of the extensive breeding conditions, subsequent lower live weight gain, which leads to delay of first insemination and first calving.
The estimated heritability ($h^2$=0.05) is low, but comparable to findings of other authors. LINDE et al. (2006), CHIRINOS et al. (2007) and PÁCHOVÁ et al. (2007) estimated heritability of $h^2$=0.04 in their studies, higher heritability was found by DUCROCQ (1999), EGGER-DANNER et al. (2005) with results of $h^2$ = 0.161-0.217 and $h^2$=0.12, respectively.
For breeding value estimation a base group of sires born between 1995 and 1999 was defined. The average and standard deviation of these sires was used as comparison

basis for all other bulls. No clear tendency for average breeding values by year of sires birth was observed (Figure 1). Younger sires seems to have lower average breeding value compared to older ones, but it may be the consequence of relatively high number of living, and therefore censored daughters. The average reliability of breeding values is also low, because of low heritability, which directly affects the results.

In conclusion survival analysis methodology was used to evaluate the impact of several factors on the risk of culling and to estimate the breeding values for longevity in Slovak Pinzgau population. The risk of culling was higher for cows with low milk production relative to herd mates, high age at first calving and decreasing herd size. The risk ratio was highest at the first half of the first lactation, decreasing during that lactation. From second lactation onwards, the risk of culling increased during and decreased between lactations. A heritability of 0.05 was estimated for the data set considered. No clear trend in average breeding values by year of birth of bulls was observed. The present study should contribute to introduction of a common breeding policy for Pinzgau cattle in Central and Eastern Europe.

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