Curve of weight gains in bulls

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Abstract

Legendre Polynomials (LP) with three to seven parameters were used to evaluate daily gains of 6,484 young bulls of Czech Fleckvieh in performance-test stations till the age of 420 days. The model comprises the following effects: station-test day STD, fixed LP within the year-test station classes, random LP of the permanent environment of an individual and random genetic LP. Each animal was weighed on average 11 times in one-month intervals. Weight gain was determined in relation to the test day, GAINTO from preceding weighing, GAINAFTER until subsequent weighing and AVERGAIN as the average of gainto and gainafter. Components of variance were determined by the REML method (REMLF90 programme). Residual variance decreased with the increasing size of the polynomial, values of information criterion AIC and –2LogL decreased at the same time. The residual variance of GAINAFTER (77 737 – 89 584) was on average slightly higher than that of GAINTO (74 812 – 82 292), GAINAFTER heritability was slightly lower. AVERGAIN had on average residual variance lower (48 114 – 71 838) and approximately twofold heritability (h^2= 0.07 – 0.12) compared to GAINTO and GAINAFTER (h^2 = 0.03 – 0.05). Heritability slightly increased with the size of polynomial, but both the curves of heritability and the curves of particular components of variance fluctuated. Heritability of cumulative gain at the age 420 days ranged on average from h^2= 0.49 to 0.86.

Keywords: cattle, bulls, growth curve, variance components, random regression, heritability

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Introduction

Bulls of Czech Fleckvieh (dual-purpose, Simmental type) cattle are performance-tested for daily gain in performance-test stations with standardised nutrition and environment. Bulls are filled into a station continually all the year round. Hence animals in different phases of growth curve are contemporaries on the day of weighing.

The objective of this paper was to compare variance components of growth curves for bulls at the age from 20 to 420 days, calculated by the random regression models with different degree of Legendre polynomial.

Review of Literature

Random regression models are increasingly used for traits with repeated measurements. Schaeffer et al. (2000) used TDM with random regression for evaluation of milk performance in cattle. Orthogonal polynomials seem to be a potential submodel for test-day model with random regression. These polynomials should be at least of degree 4 or 5 (Guo and Schaeffer, 2002). Meyer (1999a,b, 2000), and Albuquerque and Meyer (2001) evaluated genetic and phenotypic covariance functions for different growth stages in beef cattle. They described the structure of covariances between the effects of animal and permanent environment. Nobre et al. (2002) evaluated live weight in a large population of beef cattle by a random regression model and compared this evaluation with the results obtained by a multi-traits model. Differences were large because different parameters were estimated by the two models. Growth evaluation by a random regression model is likely to be more exact than that by a multi-traits model because all weightings are considered directly with corresponding covariances. Bohmanová et al. (2003) used random regression for description of differences in growth trajectories in seven beef breeds.

Material and Methods

Breeding value estimation of the Czech Fleckvieh bulls for growth curve was presented by Krejčová et al. (2003). The basic set consisted of 6,599 bulls of Czech Fleckvieh breed that were kept in seven performance test stations from 1971 to 1999. Only sire relationships were considered. The evaluated bulls were the offspring of 253 sires, and every sire had at least 6 sons. Every bull had 26 half-sibs on average. The first known weight of each animal was obtained at about 30 days of age when animals entered the station. Weighing was carried out in about 30-days intervals until approximately 420 days of age, when the performance test was terminated. On average, each bull was weighed 11 times. Only those days of weighing (test days) were left in the set, when more than 5 animals were weighed. Within one test day 26 bulls were weighed on average. After all adjustments a total of 70,615 weight records were available.

The genetic parameters for cumulative growth and daily gain until 420 days of age are determined. The following traits connected with the day of weighing were analyzed:

- body weight (kg)
- daily gain from preceding weighing (GAINTO, g/day)
- daily gain to subsequent weighing (GAINAFTER, g/day)
- average daily gain (AVERGAIN, g/day), (GAINTO + GAINAFTER)/2

Components of variance were computed by REML (REMLF90 programme, Misztal et al. 2002) for several submodels, according the degree of Legendre polynomial (LP), of the model:

$$\mathbf{y = STD + LP_F + LP_{GE} + LP_{PE} + e} \quad ,$$

where: y - measured value (weight or gain) at the age 20 – 420 days

STD - station-test-day-year effect (fixed effect)

LP_F - polynomial for average growth curve of all bulls (fixed effect) within year and station

LP_{GE} - polynomial for a genetic deviation of individual growth curve of the animal (GE) (random effect with relationship matrix)

LP_{PE} - polynomial for the deviation of growth curve of permanent environment of the animal (PE) (random effect)

e - random residual

LP with 3 to 7 parameters (2^{nd} to 6^{th} degree) was tested. Age standardisation (as) was performed during the calculation of Legendre polynomial parameters:

$$as = 2* ((x_i - x_{min}) / (x_{max} - x_{min})) - 1 \quad ,$$

where: x_i – age on the day of weighing, x_{min} – minimum age, x_{max} – maximum age

LP terms:

$p_0(as) = 1$ $\qquad$ $p_1(as) = as$

$p_2(as) = 0.5*(3*as^2 - 1)$ $\qquad$ $p_3(as) = 0.5*(5*as^3 - 3*as)$

$p_4(as) = 1/8 *(35*as^4 - 30*as^2 + 3)$ $\qquad$ $p_5(as) = 1/8*(63*as^5 - 70*as^3 + 15*as)$

$p_6(as) = 1/16*(231*as^6 - 315*as^4 + 105*as^2 - 5)$

Genetic and environment components of weight and daily gain variance were determined on the basis of genetic (G) and permanent environment (PE) covariance matrices of regression coefficients:

$$VGE_i = p_i` * G * p_i \quad ,$$

where: VGE_i – genetic variance of growth trait at age i

p_i – vector of LP parameters at age i

$$VPE_i = p_i` * PE * p_i \quad ,$$

where: VPE_i – variance of permanent environment of the animal of growth trait at age i

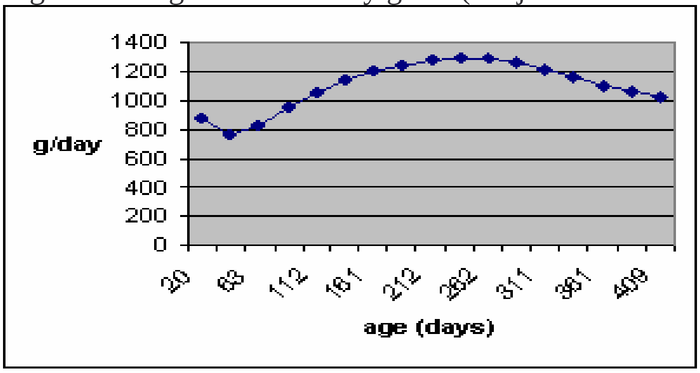
In a case of the cumulative gain, matrices G and PE are multiplied from the left and right side by the sum of vectors p_0 till p_i.

The residual component ($VRES_i$) was calculated as a ratio of the REML value of residual variability for the given model to the value of weight from the function showing the dependence of the given trait variance on the animal age i. The cumulative residual variance is a sum of components till the age (i).

Results and Discussion

Fig. 1 illustrates average gain curve. The gain curve culminates between 230 and 280 days of age.

Fig. 1: Average curve of daily gains (Krejčová et al. 2003)



Tab. 1 Comparison of model criteria

	Degree of polynomial	**Residual variance**	**-2LogL**	**AIC**
Body weight	2	55.20	552826.00	552864.00
	3	34.13	531441.33	531507.33
	4	29.63	527249.84	527351.84
	5	26.81	524751.25	524897.25
	6	24.79	523360.52	523558.52
GAINTO	2	82730	1022381.69	1022419.69
	3	79380	1020305.55	1020371.55
	4	78310	1019393.51	1019495.51
	5	77330	1018476.01	1018622.01
	6	75210	1017232.21	1017430.21
GAINAFTER	2	90060	1028021.98	1028059.98
	3	85490	1025009.40	1025075.40
	4	81450	1022869.66	1022971.66
	5	79190	1021739.17	1021885.17
	6	78150	1020814.49	1021012.49
AVERGAIN	2	72220	1022675.06	1022713.06
	3	67400	1019373.74	1019439.74
	4	55690	1015223.42	1015325.42
	5	51110	1013170.94	1013316.94
	6	48370	1011576.93	1011774.93

Table l gives residual variances, the – 2Logl and AIC for evaluated traits and the polynomial degrees. With the increasing polynomial degree the residual variance decreases. In body weight, this decrease is more intense than in gains. There is a simultaneous decrease in the values of –2logl and AIC which suggests a better suitability of models with a higher degree of polynomial.

The calculations are related to daily weight gains. Body weight is expressed as the body weight of animals at given age or by cumulative summing of daily gains. Body weight is influenced by the growth ability at a given moment of weighing and previous history of an individual. Individual animals have different histories therefore in body weight it is difficult to fully differentiate using STD the influence of environment from genetic abilities. Determination of cumulative gains for the breeding value estimation should be therefore more accurate than for body weight.

Tab. 2 shows the average values of variance components for examined submodels. It concerns components for daily gains on average for the whole observed period from 20 to 420 days of age. In body weight and cumulative gains, it shows the values at the end of the observed period at the age of 420 days.

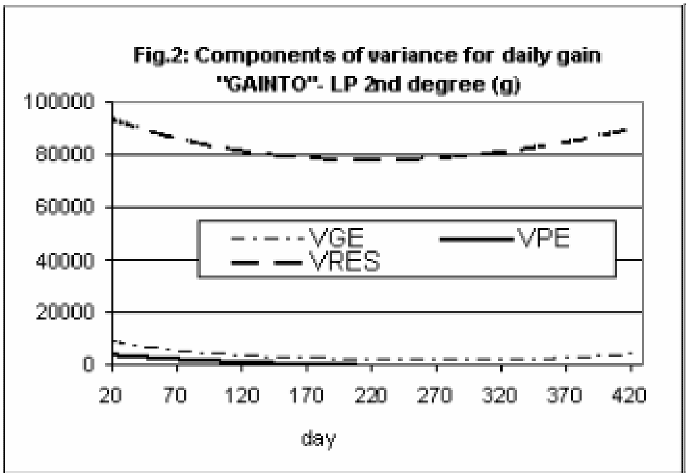
Tab. 2: Components of variance - comparison of various degrees of Legendre polynomial

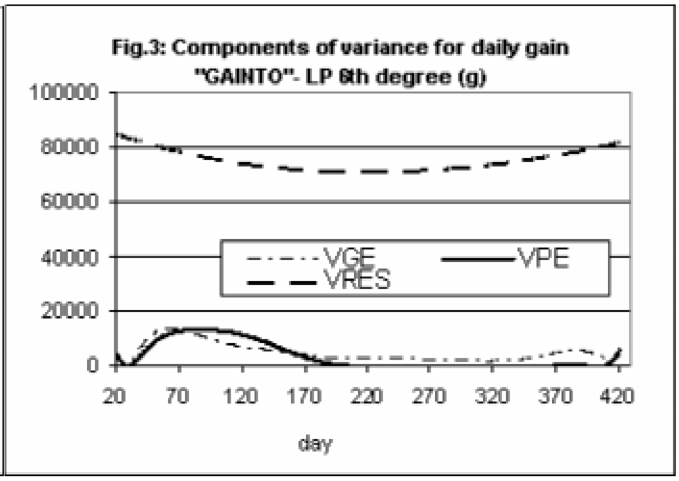
Degree of pol.		Cumulative growth at the age of 420 days(kg)				Daily gain during whole period (g)		
		Weight	Gainto	Gainafter	Avergain	Gainto	Gainafter	Avergain
2.	VGE	834.87	342.55	359.56	598.88	3 388	2 733	6 445
	VPE	639.16	58.66	20.32	347.90	923	500	6 572
	VRES	106.08	33.00	35.92	28.81	82 292	89 584	71 838
3.	VGE	788.78	339.28	374.31	627.81	4 503	3 127	7 229
	VPE	581.52	157.29	75.41	327.72	2 196	1 584	7 207
	VRES	65.59	31.66	34.10	26.88	78 960	85 038	67 044
4.	VGE	869.68	331.56	339.61	749.14	4 619	3 258	12 272
	VPE	601.98	153.76	161.72	603.06	2 530	3 967	21 518
	VRES	56.94	31.24	32.49	22.21	77 896	81 019	55 395
5.	VGE	938.22	325.15	347.99	660.57	4 381	3 557	10 600
	VPE	530.34	134.95	188.51	672.65	2 720	5 784	24 355
	VRES	51.52	30.85	31.59	20.39	76 921	78 771	50 840
6.	VGE	926.22	330.72	356.94	629.53	4 777	3 369	10 189
	VPE	472.59	139.22	179.66	636.19	3 666	6 287	25 158
	VRES	47.64	30.00	31.17	19.29	74 812	77 737	48 114

VGE – genetic component, VPE – component of permanent environment, VRES – residuum

The residual variance component in daily gains is many times higher than in genetic and permanent environment components. In comparison of daily gains, AVERGAIN shows a higher genetic variance and variance of permanent than GAINTO and GAINAFTER. On the contrary, in live body weight and cumulative gains, the individual components of variance are more balanced. The genetic component is the highest and component of residuum is the lowest. Live body weight has a higher genetic variance than cumulative gains. Genetic component and component of permanent environment of the gains have a rising ending with the polynomial degree. Even in cumulative gains, AVERGAIN has a higher genetic variance than GAINTO and GAINAFTER.

As an example, Figs. 2 and 3 show the course of the gain components in the trait GAINTO for polynomials of 2nd and 6th degree (3 and 7 parameters)





In polynomial of the 6th degree, the genetic and permanent environment components are slightly higher than in polynomial of the 2nd degree. All components for daily gain were quite balanced except for the beginning and the end of the period. Druet et al. (2003) also mentioned the typical border effects of the Legendre polynomial at the beginning and the end of the lactation and waves in the middle of lactation.

For body weight, the course of variance component in dependence on age is shown in Fig. 4.

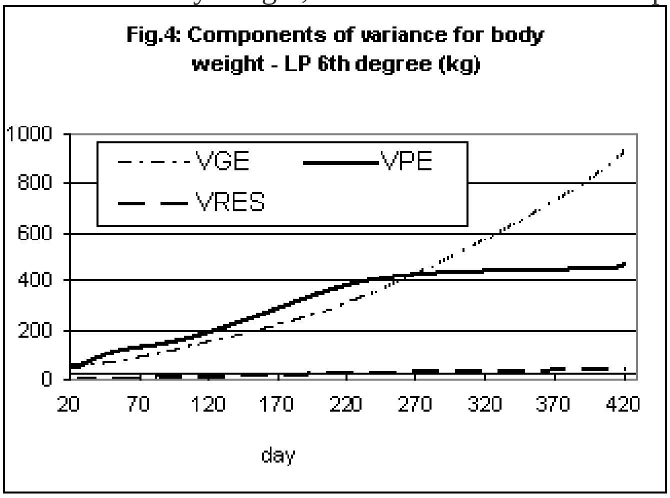


Fig.4: Components of variance for body weight - LP 6th degree (kg)

The variance of observation is quite stable for daily gain, but increases with age for body weight. The permanent environment component rises approximately up to the age of 250 days and then it keeps the same level. Meyer (2001) described variance with polynomial function to alter variance in dependence on age. Variance function has a part of measurement error and a part of polynomial function. Druet et al. (2003) used the exponential function for residual variance in the model.

Fig 5 shows the comparison of development of genetic variability of the gain GAINTO for individual different polynomials. Polynomial of the 2nd degree shows the most stable values, polynomial of the 6th degree, on the contrary, produces the highest waves. Polynomials of the 3rd and 4th degree have extreme values.

Fig. 6 shows the curves of the course of genetic component for live body weight and individual models. The course of the curves for individual polynomials is similar. The value of genetic variance increases with the polynomial degree.

The genetic component of variance for weight increases relatively markedly and continually for all models with the age of an animal. The increase of genetic variance for growth is in agreement with Meyer (1999b) and Albuquerque and Meyer (2002).

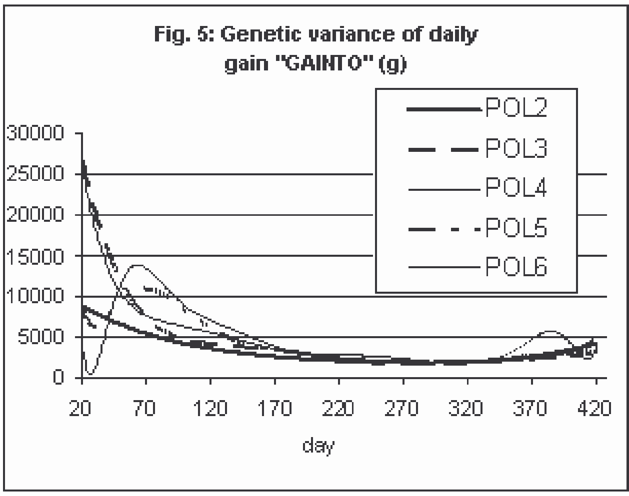


Fig. 5: Genetic variance of daily gain "GAINTO" (g)

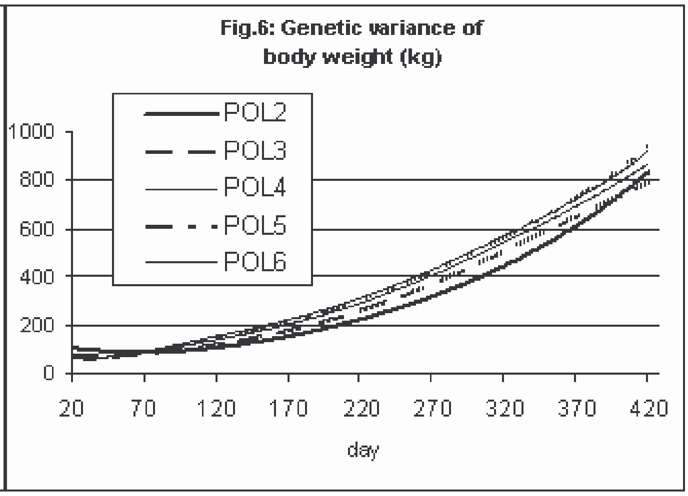


Fig.6: Genetic variance of body weight (kg)

Coefficients of heritability for individual traits and polynomial degrees are presented in Table 3. It concerns heritability for body weight and cumulative gains at the end of the observed period and average heritability of the gains in the course of the whole observed period.

Tab. 3: Heritability - comparison of various degrees of Legendre polynomial

Degree of polynomial	Cumulative growth at the age of 420 (kg)				Daily gain during whole period (g)		
	Weight	Gainto	Gainafter	Avergain	Gainto	Gainafter	Avergain
2.	0.53	0.79	0.86	0.61	0.04	0.03	0.07
3.	0.55	0.64	0.77	0.64	0.05	0.04	0.08
4.	0.57	0.64	0.64	0.55	0.05	0.04	0.11
5.	0.62	0.66	0.61	0.49	0.05	0.04	0.11
6.	0.64	0.66	0.63	0.49	0.05	0.04	0.12

Heritability of body weight and cumulative expression of body weight is many times higher than in daily gains. There is a great influence of „every day" random errors on the gain, in cumulative expression it is total sums in which the random errors are reciprocally eliminated and therefore the residual variability is relatively lower.

In daily gains AVERGAIN shows approximately twofold heritability than GAINTO and GAINAFTER. There appears again a lower variability of the trait calculated as an average (AVERGAIN). The polynomial degree is connected with a slight tendency for the increase in heritability coefficient.

The course of heritability coefficient of daily gains is shown in Fig. 7. Heritability in the course of growth is most stable for the polynomial of the 2nd degree. Polynomials of the 6th and 5th degree form a wave at the beginning.

The course of heritability in cumulative gains is given in Fig. 8. Polynomial of the 2nd degree reaches, except for the beginning, the highest values in the whole course. Starting with day 150, the course of the curves in all polynomials is similar.

Fig.7: Heritability of daily gain "GAINTO"

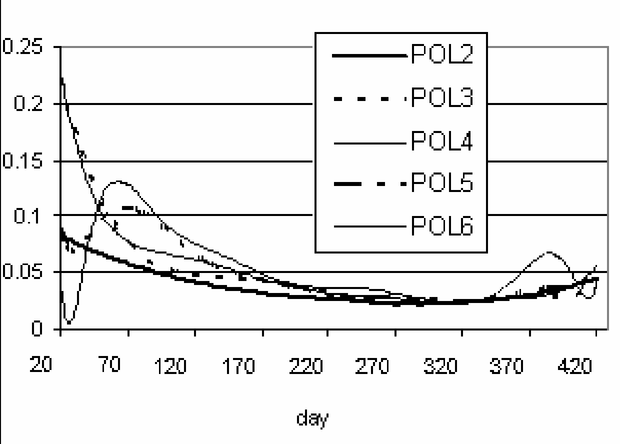
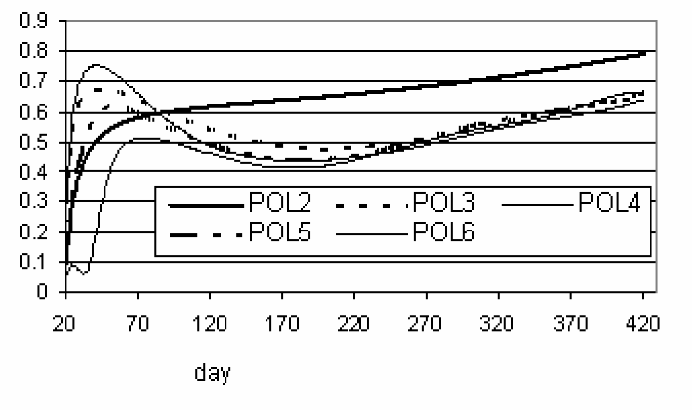
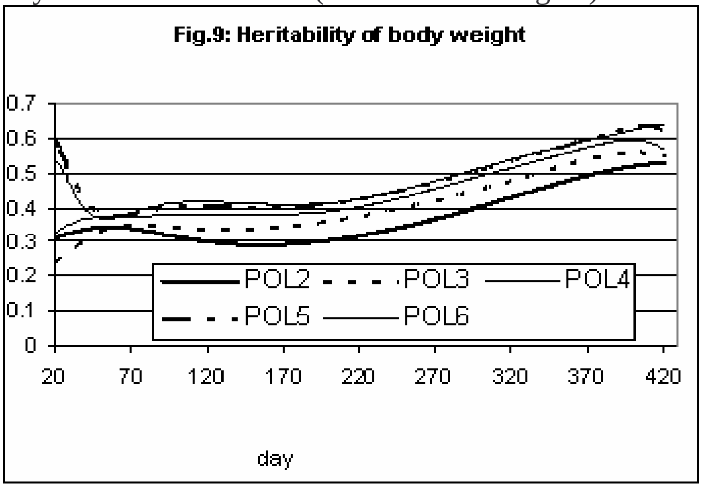


Fig.8: Heritability of cumulative daily gain "GAINTO"



The course of heritability for live body weight according to individual polynomials is presented in Fig. 9. For body weight, we can observe the accumulated share of genetic component and descended share of residuum with the increase of degree of polynomial. Therefore heritability increases, too (see Fig. 9). The shape of the curve of heritability in the course of growth for all degrees of polynomial is well-proportioned from 70th day of age. Until that time the difference between degrees of polynomials are marked. The attained heritability increases with the degree of polynomial. Polynomials of higher degrees have extreme values at the beginning. From this viewpoint, the 4th degree polynomial seems to be sufficient.

The coefficient of heritability of body weight is bigger than this referred by Meyer (1999b) and Albuquerque and Meyer (2001). Meyer (1999b) shows the heritability rather stable in the period from 100 till 300 days of age. Albuquerque and Meyer (2001) refer the highest maternal and the lowest direct heritability at the age of 150 – 200 days. Meyer (2001) refers for Hereford a decreasing heritability of direct effect in range approx. 0.40 till 0.20 from birth till the age of 300 days and an increasing heritability of maternal effect from 0.10 till 0.15 in the same age period. But Meyer (2002) declared practically linear increase of heritability with age. Bogdanovic et al. (2002) determined variance components for growth traits in Simmental bulls. They evaluated weight and gain in different segments of growth. Their coefficient of heritability was lower than ours (0.29 for lifetime gain).



Degree of polynomial influences the level of heritability, but do not have any bigger influence on the course of genetic variance and heritability for body weight and cumulative growth. The course of cumulative growth for gain till weighing and average gain is, similarly as body weight, balanced from 90th-100th day of age (Fig. 8).

Conclusion

REML calculation requires much higher number of iterations to reach the acceptable level of convergence for daily gain than for body weight.

Every-day residual variability influences strongly daily gain. The heritability of daily gain is much lower than cumulative growth.

Polynomials of higher degree show border deviations from the common trend.

Polynomials of higher degrees show a lower residual variability and higher heritability

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