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İ Ç İ N D E K İ L E R / C O N T E N T S

The Comparison of Growth Curve with Different Models in Anatolian Buffalo

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The aim of this study is determining the relationship between body weight and age on growth curve models and selecting the best fitted model. The study was conducted in live weight records maintained a total of 54 male and female buffalo heads for a year. Richards, Gompertz, Logistic and Von Bertalanffy models are used as growth model in recent study. The model parameters were calculated and the comparisons among the models are materialized according to goodness of fit criteria (R^2, R^2_{adj}, MSE, AIC and BIC). As a result, all models were indicated that high and similar goodness of fit criteria. Richards and Von Bertalanffy models are the most appropriate (R^2=0,996; R^2_{adj} =0,993; MSE=62,71; AIC=42,47; BIC=27,29) for female animal and (R^2=0,998; R^2_d =0,998; HKO=18,51; AIC=30,51; BIC=12,65) male animal, respectively.

Key words: Anatolian Buffalo, Growth Curve, Growth Curve Models

Mandalarda Büyüme Eğrisinin Farklı Büyüme Modelleri ile Karşılaştırılması

Araştırmanın amacı, mandalarda canlı ağırlık ile yaş ilişkisinin farklı büyüme modelleri kullanarak belirlenmesi ve en uygun modelin seçilmesidir. Çalışma bir yıl süre ile canlı ağırlık kayıtları tutulan toplam 54 baş dişi ve erkek mandalarda yürütülmüştür. Modellemede kullanılan modeller ise Richards, Gompertz, Logistic ve Von Bertalanffy modelleri olmuştur. Her bir model için model parametreleri hesaplanmış, modeller arasındaki karşılaştırmalar belirleme katsayısı (R^2), düzeltilmiş belirleme katsayısı (R_d), hata kareler ortalaması (HKO), Akaike (AIC) ve Schwarz Bayesyan (BIC) uyum kriterlerine göre yapılmıştır. Sonuç olarak tüm modellerde yüksek bir uyum olmakla birlikte en yüksek dişi mandalarda Richards modeli (R^2=0,996; R^2_d =0,993; HKO=62,71; AIC=42,47; BIC=27,29) ve erkek mandalarda ise VonBertalanffy modeli (R^2=0,998; R^2_d =0,998; HKO=18,51; AIC=30,51; BIC=12,65) bulunmuştur.

Anahtar Kelimeler: Anadolu Mandası, Büyüme Eğrisi, Büyüme Eğrisi Modelleri

Introduction

In recent years, although there is an increase trend on buffalo breeding in Turkey and the breeding is continuing under elemental conditions. Especially it is gratifying that studies in animals' records being kept as they never done before. When examining statistic data in our country, end of 2013, total buffalo number was 117591, female buffalo number was 51940 (TUIK 2014). In the world, there are 200 million heads buffalo. 83,5% of this buffalo population is breeding in South East Asia countries (Borghese 2013). Buffaloes, rather than cattle, are much more endurable to diseases, bad maintenance and breeding conditions. Concurrently, they are able to benefit from rough feeds which are cheap, high-rated cellulose and less quality (Kreul and Sarican 1993, Soysal 2009, Sahin et al. 2013).

The growth concept starts with fertilization of egg cell in mother's abdomen and continues until mature age. For this reason, the growth, considered in two phase as before birth and after birth. Increasing live weight consubstuntiated with growth animal is under genetic and environmental effects as it is in other characteristics. The model used in growth of modelling and with the parameter in this model, animal's health, age of using at breed in and ideal cutting age could be estimated (Akbas 1995).

With meat yield in buffaloes, the growth curve which is change of growth according to time may be evaluated as an important evaluation criteria in breeding studies to be held about meat. Growth curve's determination with nonlinear mathematic models has an important role in animal breeding also on determination of food matter requirements. In setting down of growth curve, Brody, Logistic, Gompertz, Richards and Von

Bertalanffy models are used widely (Akbas 1995, Sengul and Kiraz 2005).

Madad et al. (2013) are researched some environmental factors effecting various yield characteristics in Azeri Buffaloes. They found calving year and calving season are important for yield characteristic. Sekerden (2010) is researched various body measures and growth characteristic for 0-12 month Anatolian and Anatolian x Italian crossbreed buffaloes and various environmental effects on these characteristics. As to all characteristics they stated that crossbreed genotype has growing faster. They determined that on 12 month age, live weight averages are 182.3 kg in males and 160.4 in females (Akbulut et al. 1994).

In many studies, it is found that gender factor has significant effects on growth. Especially, growth is much quicker in male animals than females (Salama and Schalles, 1992, Sekerden et al, 1997). Sahin et al. (2014) executed changing of Anatolion Buffalo's live weight's changing according to time with non-linear models. They used, Logistic, Richards, Gompertz and Brody models, in study. They found that while coefficients of determination fo Logistic, Brody, Gompertz, and Richards for male animals are 0.94, 0.93, 0.95 and 0.97, respectively, in female animals they are respectively, 0.96, 0.92, 0.96 and 0.98. As a result, they specified that Richards model is best identifying model for both gender. In this materialized study, by benefiting from buffaloes' known as Anatolian Buffalo monthly recording weight yield records, it is studied that modelling of growth curve with different models according to birth to 12 month age and specifying the best fit model between used models.

Material and Method

The animal material consisted of 54 heads animal which scaled live weight of 12 month age period raised in a special company in Istanbul, animal material of this study. Numbers of the animals' are 23 females and 31 males. Live weights recorded monthly from birth to 12 month with 100 g sensible weigh bridge. Animals raised intensively without letting out to meadow. Breeding is realized inside with breast milk, first 15 days and then next 6 month, the breeding consist of 18% protein feed with breast milk and after 6 month it continued by ablactating and feeding (compact feed, grass and razmol). Breast milk had to be given 10% of live weight.

Models used in modelling are Richards, Gompertz, Logistic and Von Bertalanffy (Richards, 1959). Model parameters calculated for each model and comparison between models were performed according to fit criteria of determination of coefficient (R^2), adjusted determination of coefficient (R^2_d), mean squares of error (MSE), Akaike (AIC), Schwarz Bayes (BIC) (Akaike, 1974, Schwarz, 1978, Narinc et al. 2010). Functions forms of used models stated in Table 1 as R^2=1-(SSE/SST), $R^2_d=R^2-(k-1/n-k)(1-R^2)$, MSE=SSE/(n-k), AIC=n.ln(SSE/n)+2k and BIC= n.ln(SSE/n)+k.ln(n). Ranked among in this model, it is showed that A: mature live weight, B: rate of gained weight after birth to mature weight, Yt: weight at the age of t, t: animal's age at the time of scaling, k: intrinsic growth rate, m: at the time inflection point when the curve turn into increasing to decreasing. Modelling and parameter estimations belonging to models are materialized on Statistica package software(Statistica1994).

Table 1. Non-linear models used to estimate growth curve

Models	Expression
Richards	$W_t=A.(1-B.\exp(-k.t))^m$
Gompertz	$W_t=A.\exp(-B.\exp(-k.t))$
Logistic	$W_t=A.(1+B.\exp(-k.t))^{-1}$
Von Bertalanffy	$W_t=A.(1-B.\exp(-k.t))^3$

W_t: Body weight in at age t; A,B, k and m: parameters of model; t:age (day)

Results and Discussion

Parameter estimations and fit criteria for models used in this study are presented at Table 2 and 3, according to animal gender. A parameters, according to female and male animals, is found highest at Richard model. In all models, A parameters presenting mature weight of male gender are found higher than females. When examining coefficients of determination Gompertz, Logistic, Von Bertalanffy and Richard models are found as 0.994, 0.993, 0.994 and 0.996, respectively. As to male animals it is found 0.998 for all models.

As to mean squares of error for female animals, Gompertz, Logistic, Von Bertalanffy and Richards models are 80.74, 100.7, 73.99 and 62.71, respectively. As to male animals' all models they are 20.16, 27.36, 18.51, 21.10, respectively. Mountly weight recorded animals, observed weights according to gender and estimated weights existing in models are given at Table 4.

In represented study there is a high fitting between all models and highest fitting in females is Richard model and in males it is Von Bertalanffy model. In similar studies Sahin et al. (2014) found coefficient of determination in buffalo for Logistic, Brody, Gompertz and Richard for male animals as 0.94, 0.93, 0.95 and 0.97,respectively and as to female animals it is 0.96, 0.92, 0.96, 0.98, respectively. Richard model is defined as best describing model for both gender. Fundora et al. (2006) found Logistic model as much fitting in water buffaloes and Araujo et al. (2012) found Logistic and Gompertz model as much fitting in Murrah breeds. In another study, non-linear mathematical functions used as Brody, Gompertz, Richards, Bertalanffy and Verhulst. These models were compared in several buffalo production systems in Colombia. As a result growth was better described by the curves by Brody and Gompertz (Agudelo-Gomez et al. 2009). Observed daily weights and estimated weights' ,according to models, changing as to time presented at Figure 1 and 2.

Table 2. The mean and standart error of growth curve parameters

Gender	Model	A	B	k	m
Female	Gompertz	123,5±7,14	1,26±0,18	0,010±0,003	--------
	Logistic	121±6,73	2,24±0,60	0,019±0,05	--------
	Von Bertalanffy	124,7±7,44	0,35±0,04	0,012±0,003	--------
	Richards	152,4±61,31	-2,31±1,45	0,003±0,006	28,80±9,18
Male	Gompertz	160,9±12,32	1,54±0,08	0,007±0,001	--------
	Logistic	148,5±8,83	3,09±0,35	0,011±0,001	--------
	Von Bertalanffy	168,7±15,13	0,41±0,01	0,005±0,001	--------
	Richards	208,7±119,9	-1,06±1,09	0,002±0,004	31,80±4,61

Table 3. The goodness of fit criteria based on different models.

Gender	Model	R^2	R_{adj}^2	MSE	AIC	BIC
Female	Gompertz	0,994	0,991	80,74	48,18	30,33
	Logistic	0,993	0,988	100,7	50,83	32,98
	VonBertalanffy	0,994	0,991	73,99	47,14	29,28
	Richards	0,996	0,993	62,71	42,47	27,29
Male	Gompertz	0,998	0,998	20,16	31,53	13,68
	Logistic	0,998	0,997	27,36	35,20	17,34
	VonBertalanffy	0,998	0,998	18,51	30,51	12,65
	Richards	0,998	0,997	21,10	29,40	14,22

Table 4.Observed and predicted weight values for each models

Gender	Age(day)	Observed Weight Values (kg)	Predicted Weight Values(kg)			
			Gompertz	Logistic	Von Bertalanffy	Richards
Female	1	32	35,51	37,74	34,63	30,51
	24	45	50,02	49,91	50,19	54,15
	50	78	65,87	64,75	66,31	69,29
	109	92	93,74	94,33	93,46	90,71
	173	108	110,314	111,66	109,78	105,43
	233	110	117,59	117,86	117,43	115,19
	280	116	120,38	119,70	120,59	121,11
	359	134	122,42	120,71	123,14	128,78
Male	1	32	34,56	36,56	33,85	32,32
	36	52	48,40	48,24	48,64	49,61
	78	63	65,88	64,41	66,47	67,83
	151	99	94,39	93,88	94,45	94,33
	216	115	114,85	115,71	114,48	113,51
	255	118	124,55	125,42	124,22	123,39
	289	132	131,54	131,84	131,43	131,15
	342	143	140,07	138,75	140,58	141,83

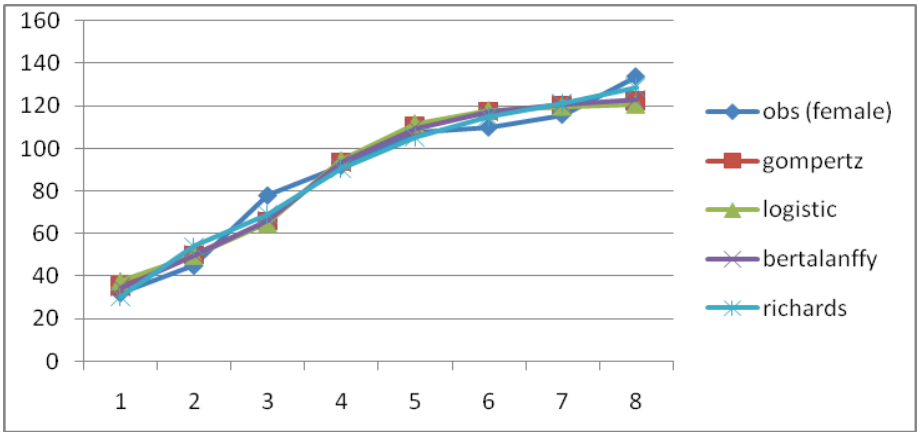

Figure 1. Observed and predicted growth curve of models for body weight of female.

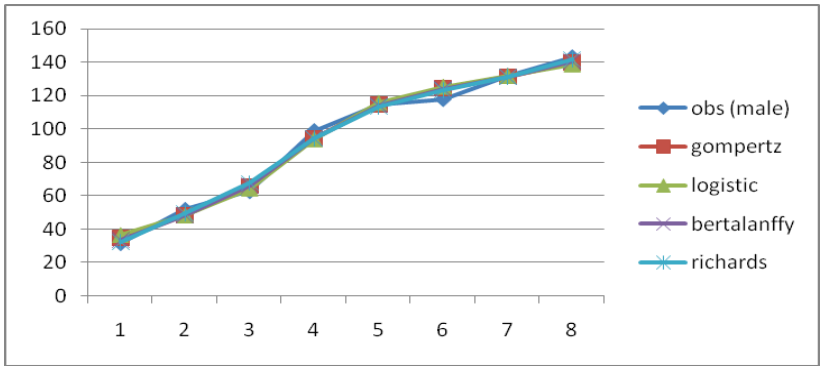

Figure 2. Observed and predicted growth curve of models for body weight of male.

Conclusion

As a result, all models are indicated that high and similar goodness of fit criteria. Richards and Von Bertalanffy models are the most appropriate (R^2=0,996; R^2_{adj} =0,993; MSE=62,71; AIC=42,47; BIC=27,29) for female animal and (R^2=0,998; R^2_d =0,998; HKO=18,51; AIC=30,51; BIC=12,65) male animal, respectively.

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