A Model for Prediction of the Buffalo and Cattle male Calves' live Weight

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Abstract: The buffalo and cattle population in Egypt reached about 4.898,893 and 3,476,396 heads, respectively, in 2019. The buffalo and cattle meat production represented around 43% and 45% of the total meat production in Egypt, respectively, and the average carcass weight of buffalo and cattle reached 318 kg and 336Kg in 2019. About 50% of livestock numbers are slaughtered off-slaughter houses due to a shortage in the capacity of slaughterhouses and other financial and administrative reasons. The conducted field survey of this study showed that the majority of Egyptian livestock markets lack live weight scales, and if available, they are expensive and frightening for the animals. Therefore, numerous feedlot enterprises hire an agent who can visually forecast the expected live weight of the exhibited feeder calves for sale in the market at a high charge. Most of the models to predict the weight of live cattle-bulls knowing the chest circumference were lacking such models for buffalo-bulls and were linear models that fit only limited periods of cattle-fattening. The sample survey included 500 buffalo males and 340 cattle males of different live weights from 14 villages in 4 provinces in the Nile Delta. The data were used to estimate the best-fitted model for Egyptian livestock. This study showed that the best-fitted model was curved linear. It was a quadratic form. For empirical application, the study designed a table to predict the live weight of buffalo and cattle males at a range of 100-200 cm chest circumference. The results showed that a 1% increase in the chest circumference was associated with a 2.4% and 2.8% increase in the buffalo and cattle male's circumference, which implicitly reflects higher live weight gain of cattle than buffalo males and better meat quality. Therefore, the farm price of cattle feeder males surpassed the buffalo by $1000.

Keywords: Prediction Model, Fed Calves, Egyptian Livestock Maekets.

INTRODUCTION

The buffalo and cattle population in Egypt reached about 4.898,893 and 3,476,396 heads, respectively, in 2019. The total number of slaughtered buffalo and cattle in the same year was about 1,088,548 and 1,134,412, respectively, that were compiled and calculated [1], i.e., the off-take rate was around 31.3% and 23%, respectively. The average carcass weight of buffalo and cattle reached 318 kg and 336Kg in 2019. The buffalo and cattle meat production represented around 43% and 45% of the total meat production in Egypt, respectively, which was measured as carcass weight in that year. They were compiled and calculated from [1]. However, about 50% of livestock are slaughtered off-slaughter houses due to a shortage in the capacity of existing slaughterhouses and high fees that should be paid for such marketing function [2]. Therefrom, numerous feedlot enterprises hire agents at relatively high charge who have experience in guessing the body live-weight of the exhibited calves visually for sale in the livestock market. They, normally, depend upon the morphological traits of the calves, either feeder calves (for fattening) or fed calves (for slaughtering) [3].

This study conducted a field sample survey at livestock markets of Egypt, as will be shown later. Even though the buffalo and cattle feeder-calves trade is widespread in the Egyptian livestock markets, this survey showed that most Egyptian livestock markets lack scales for liveweight, and if available, weighing animals would be expensive and frightening for the animals. Therefore, numerous feedlot enterprises hire agents at relatively high charge rates to judge or forecast the liveweight of the exhibited salable calves in the market sites. Such a fundamental problem was displayed by most of the respondents who were interviewed at the livestock markets. Pricing and grading in livestock markets require basically knowing the age and live weight of an animal, which apparently, are indicators for the expected, derived carcass weight and its purchase price [2]. The exhibited buffalo and cattle calves and bulls for sale in livestock markets in Egypt are purchased either as feeder calves for feedlot system or finished fed calves for slaughtering.

Fioretti (2012) [4] cited that the ability of farmers to estimate the body liveweight of cattle enables them to evaluate the price and the yield of meat that can be obtained and consequently the expected profit. As castration is forbidden in Egypt by legislation, all feedlot animals are called bulls or male calves as they are within the age of 1-3 years [5]. Therefore, the objective of this study was to estimate a quantitative mathematical model to predict the liveweight of feeder

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or fed buffalo and beef bulls to overcome the obstacles of the lack of animals' body weight scales in most livestock markets and avoid the associated high cost and high risk.

Several recent studies have developed equations to predict the weight of live cattle-bulls knowing the chest circumference. The pioneers in finding such relationships were Brody *et al*. (1937) [6]. The available literature has shown a strong correlation between chest circumference and cattle live body weight. Such relation helped develop equations to predict the weight of live animals, knowing the circumference of the chest [7, 8].

However, all previous studies had applied such a relationship on cattle rather than buffalo. Secondly, they classified the cattle and designed a linear relationship between body liveweight and chest circumference. Therefore, this study aimed to estimate mathematical models for buffalo bulls and beef bulls in Egypt's livestock markets that fit all-male classes, either by age or body weight. The final target of this objective was to design a scale-measure "digital-bar" associated with a list in a table to show different values for the circumference of the chest corresponding to each live weight. Even if a scale were available in the market, it would be much easier to measure the chest's perimeter than loading the animal on a scale, particularly if it has not passed through such an operation before.

DATA AND METHODOLOGY

The sample was a "multistage stratified random sample from Lower Egypt (Nile delta region). The 1st stage included the selected providences, and the 2nd stage included the districts where the main livestock markets are located. The two strata represent the livestock type (buffalo and cattle bulls). Even though the ability of respondents to participate in the research work and the limited budget allocated for the study had limited the sample size, it was a reasonably larger size than the sample size of several previous studies dealing with this issue. The sample size and structure are presented in (Table **1**). Data were collected on the chest circumference and liveweight of buffalo and cattle males from villages in districts within the frontiers of 6 provinces "Sharkia, Qalyoubia, Monoufia, Kafr Al Sheikh, Gharbia and Giza". The sample size included 500 buffalo males and 340 cattle males, as shown in (Table **1**).

A recent study has designed a linear model for predicting zebu cattle live weight using live animal measurements by using a total of 247 Sudanese indigenous cow-bulls [7]. The cow-bulls live weights ranged from 170 to 390 Kg. The study revealed that heart circumference around the hump had the highest correlation coefficient with live weight ($r = 0.83$, $p<0.001$) compared with other body measurements. Grouping data according to live weight indicated that heart circumference around the hump in group B (medium weight) and C (heavyweight) had shown that the closest correlation coefficient with live weight was $r = 0.66$ and 0.86, respectively. The authors concluded that their results gave more confidence in using the former measurement to predict the live weight of humped cattle. The regression analysis of live weight on heart circumference around the hump was highly significant ($P<0.001$), and the regression lines indicated a linear relationship. The regression equations were also obtained to estimate the live weight of the "heavy", "medium", and “light” weight bulls. The general equation for prediction of live weight of the humped cattle was as follows:

Table 1: Structure of the Field Sample Survey

Province	Number of Villages	Cattle Bulls	Buffalo Bulls
Al Sharqya	3	187	80
Al Qalyoubia	4	30	213
Al Monofia	5	38	157
Al Giza	2	0	50
Kafr Al Sheikh	2	40	0
Al Gharbia	2	45	0
Total	18	340	500

Source: compiled from the sample survey data.

Y = 2.4573x – 92.472(± 0.36), Where:, Y = live weight (Kg) and X = heart circumference around the hump (cm).

However, the present study on cattle and buffalo bulls in Egyptian markets considered the concept around the mathematical form of the model applied by the pioneer study of Brody *et al*. (1937) [6]. This is because of the large sample size they introduced in the estimation. They showed that in the case of data representing different growth stages and age groups, the non-linear power (allometric) equation (double-log equation) gave the best-fitted model for that kind of data. The relation between body weight and chest circumference of dairy cattle of mixed ages may be formally represented by the following equation:

$Y=aX^n$,

Where Y is bodyweight and X chest circumference.

The value of the exponent " n " was of the order 2.82, i.e., the percentage increase in body weight tended to be about 2.82 times as great as the percentage increase in chest circumference, but the estimated model of that study for each of the 6 groups of investigated cattle showed that the values of "n" ranged from 2.72 to 2.88. There were also variations within groups and with size in the value of the intercept coefficient "a". It appeared that the relationship between weight and chest circumference was not altogether independent of nutritional level. However, the relation between weight and chest circumference was close enough to estimate weight from chest circumference. For the theoretical generalization and within certain weight limits, a power function of chest circumference as indicated by the equation $Y = aX^n$ was satisfied. It was fitted by the method of least squares for the weight-chest pairs of measurements.

The current study considered the nonlinearity adopted by Brody *et al*. [6] in estimating the target model. They showed in their article that " within certain limits of liveweight, a power function of chest circumference as indicated by the equation $Y = ax^n$ was satisfied. Therefore, this study also estimated a function of the quadratic form (polynomial function) to cover almost all bodyweight range of buffalo males and cattle males exhibited for sale in the livestock markets. Accordingly, both models were estimated to choose the best-fitted one for buffalo and cattle bulls in the Egyptian livestock market.

Power Function

The following mathematical function was applied to estimate the relationship between the liveweight (Y_i) and the chest circumference (X_i)

$$Y_i = ax_i^b \quad (1)$$

Where:

Y_i = liveweight in kg of livestock type i

X_i = Chest circumference in cm of livestock type i

a =the intercept in kg

i = b for buffalo bull c for cattle bull =c

b = Coefficient of response (regression coefficient) as the relative change in live weight associated with 1% change in chest circumference.

The power function is a non-linear transitional form that can be transformed to linear form by the logarithmic transformation of equation (1) to estimate its parameters (equation 2).

$$Ln\ (Y_i) = Ln\ (a) + b\ ln\ (X_i) \quad (2)$$

Where Ln = natural logarithm of the variable(s)

Polynomial Function

The other version of the model was estimated by applying the Polynomial regression equation, where only two terms were introduced, which were the linear term and the quadratic one (Equation 3)

$$Y_i = a + b_1x_i + b_2x_i \quad (3)$$

Where:

Y_i, X_i, and a = were Defined the same as in equation (1)

b_1, b_2 = Estimated response coefficients of live weight to the chest circumference

RESULTS AND DISCUSSION

The basic descriptive statistical estimates of the sample (The range and SD) were presented in (Table **2**). It displays the value of the minimum, maximum, and standard deviation of the chest circumference and liveweight of the number of heads of buffalo and cattle bulls in the drawn sample.

Table 2: Min., Max., and SD of the Sample Data for the Concerned Variables

Livestock Type	Variable	Range		SD
		Minimum	Maximum	
Buffalo Male	Liveweight (Kg)	100	334	42
	Chest Circumference (CM)	102	175	13
Cattle Male	Liveweight (Kg)	93	420	83
	Chest Circumference (CM)	100	181	18

Source: compiled and calculated from the sample survey data.

The clear difference between the maximum live weight of the sampled buffalo males and the cattle sampled males reflected the wide variation in cattle breeds in the Egyptian market of Holstein, Friesian, and their crossbred with native cattle. Such variation was shown by the much larger value of the standard deviation of cattle male's liveweight and chest circumference.

As the estimated model was applied for both buffalo and cattle males, either as male feeder calves or fed bulls, the results and associated discussions were presented under two sections. Each was allocated for one type of animal.

Buffalo Male Calves and Bulls

Whereas equation (4) shows the estimated power form of the buffalo male calf and bull's model and its linear transformation in equation (5), equation (6) shows the estimated quadratic form of the buffalo male calves and bull's model. The values in parentheses under the estimates of the parameters of each equation are the SE of the corresponding regression coefficient.

$$Y_b = 0.0009\, X_b^{2.4744} \quad (4)$$

$$(0.704) \qquad (R^2 = 0.9451)$$

$$Ln\,(Y_b) = -7.018977 + 2.474352\, \ln\,(X_b) \quad (5)$$

$$Y_b = 201.997108 - 3.674401(X_b) + 0.025245\,(X_b^2) \quad (6)$$

$$(1.09450) \quad (0.0071) \qquad (R^2 = 0.9501)$$

Both buffalo models provided evidence that the relation between the liveweight and chest circumference of a buffalo male is not of a linear form. It is either a non-linear (Power) form or a curve-linear form (polynomial). Despite the slightly larger value of R^2 of the quadratic form, it was selected because it is more suitable and easier for empirical use than a non-linear equation (powder form), particularly within a wide range of livestock ages and live weights. The t-test indicated that the regression coefficients derived from the two models' forms were statistically significant at a significance level of less than 5%.

Table **3** shows the predicted values of the liveweight of buffalo males for meat production by measuring the male chest circumference using the quadratic equation (6). Figure **1** compares the actual and predicted values of Buffalo male's liveweight, derived from applying equation (6). The results showed that the differences between the actual and predicted liveweight were not apparent, i.e., the estimated values have almost coincided with the observed ones. The study recommends applying such a metric scale to get the body liveweight of buffalo males. Even though it is recommended to repeat such work on a larger sample that includes Upper Egypt livestock markets (southern Egypt's providences).

Cattle Male Calves and Bulls

Simulating the same models estimated for buffalo, the cattle models were estimated for the cattle where the dominant breed is crossbred of domestic with either Holstein or Frisian. However, about 10% of cattle male calves and cattle bulls are either pure foreign breeds or traditional (zebu) breeds [3]. Therefore, the field data (Table **2**) showed a much higher standard deviation in male cattle weights for sale in the livestock markets than buffalo males. Equations (7) and (8) showed the estimated allometric model, and its linear transformation and equation (9) showed the quadratic model. All estimated response parameters of the estimated models were statistically significant at <5% probability level. The quadratic form was selected because of the same reasons mentioned above for the buffalo model. Table **4** presents the predicated liveweight of cattle male calves (feeder's calves) and the predicted liveweight of cattle bulls (fed calves). It should be mentioned that the legislations prohibit slaughtering cattle calves of less than 200Kg liveweight. Therefore, the calves up to such weight are considered feeder's calves, i.e., they are sold for fattening and associated with the high sale price.

$$y = 0.0002\ X^{2.8282} \quad (7)$$

$$(0.052) \qquad (R^2 = 0.923)$$

$$\ln(y) = -8.657532 + 2.82808 \ln X \quad (8)$$

$$y = 112.72093 - 2.83627X + 0.025009\ X^2 \quad (9)$$

$$(0.0654) \qquad (0.00822) \qquad (R^2 = 0.925)$$

The estimated power (allometric) models for both buffalo and cattle provided (Equations 5 and 7) a reasonable criterion for comparing both types of livestock with respect to the relative response of body weight to the change in the chest circumference. This is because such a model's estimated response coefficient is the average relative change in liveweight due to a 1% change in chest circumference (average elasticity of response). Estimating models (4) and (7) showed that a 1% increase in the chest circumference was associated with about 2.5% increase in the liveweight of a buffalo male and a 2.8% increase in the liveweight of a cattle male. Such a result reflects, implicitly, the slower growth of the buffalo liveweight than cattle. This is because the Egyptian buffalo as a river buffalo strain is mainly a dairy buffalo breed rather than for meat, while the current dominant breed of cattle in the Egyptian market is a dual-purpose breed [5, 9, 10]. Previous studies also showed that the beef as feedlot is of more mumbled and lean meat cuts than

Table 3: Predicted of Buffalo Bull Liveweight at Different Chest Circumferences Measures

Chest circumference (CM)	Live Weight (Kg)	Chest circumference (CM)	Live Weight (Kg)	Chest circumference (CM)	Live Weight (Kg)	Chest circumference (CM)	Live Weight (Kg)
100	87	125	137	150	219	175	332
101	88	126	140	151	223	176	337
102	90	127	143	152	227	177	343
103	91	128	145	153	231	178	348
104	93	129	148	154	235	179	353
105	95	130	151	155	239	180	359
106	96	131	154	156	243	181	364
107	98	132	157	157	247	182	369
108	100	133	160	158	252	183	375
109	101	134	163	159	256	184	381
110	103	135	166	160	260	185	386
111	105	136	169	161	265	186	392
112	107	137	172	162	269	187	398
113	109	138	176	163	274	188	403
114	111	139	179	164	278	189	409
115	113	140	182	165	283	190	415
116	115	141	186	166	288	191	421
117	118	142	189	167	292	192	427
118	120	143	193	168	297	193	433
119	122	144	196	169	302	194	439
120	125	145	200	170	307	195	445
121	127	146	204	171	312	196	452
122	129	147	207	172	317	197	458
123	132	148	211	173	322	198	464
124	135	149	215	174	327	199	471

Source: Estimated from equation (6).

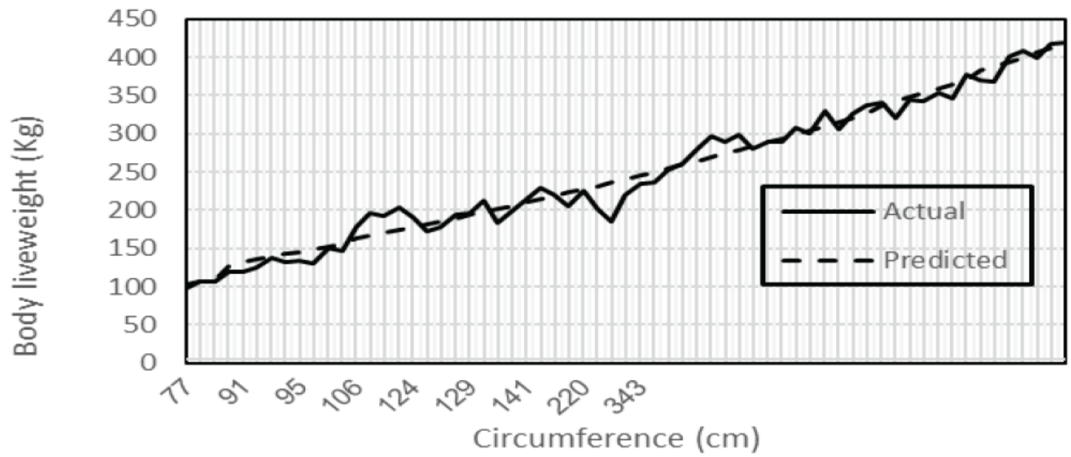

Figure 1: Actual and predicted buffalo bulls body live weight.
Source: Field Survey Data and Equation (9).

Table 4: Predicted of Cattle Bull Liveweight at Different Chest Circumferences Measures

Live weight	Chest Circumference	Live weight	Chest Circumference	Live weight	Chest Circumference	Live weight	Chest Circumference
315	163	214	142	136	121	79	100
320	164	219	143	139	122	81	101
326	165	223	144	142	123	84	102
331	166	227	145	146	124	86	103
337	167	232	146	149	125	88	104
342	168	236	147	152	126	91	105
348	169	241	148	156	127	93	106
353	170	245	149	159	128	96	107
359	171	250	150	163	129	98	108
365	172	255	151	167	130	101	109
371	173	259	152	170	131	103	1010
376	174	264	153	174	132	106	111
382	175	269	154	178	133	109	112
388	176	274	155	182	134	112	113
394	177	279	156	186	135	114	114
400	178	284	157	190	136	117	115
406	179	289	158	194	137	120	116
412	180	294	159	198	138	123	117
		299	160	202	139	126	118
		304	161	206	140	129	119
		310	162	210	141	133	120

Source: Estimated from Equation (6).

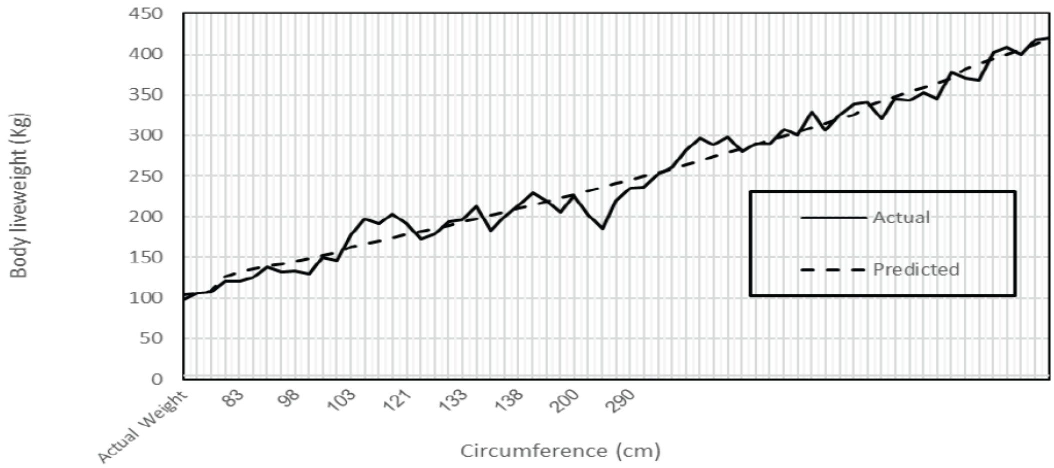

Figure 2: Actual and predicted cattle bulls body live weight.

Source: Field Survey Data and Equation (6).

Table 5: Meat Buffalo and Cattle and Buffalo Liveweight Farm Price ($/ton)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Annual Average
Buffalo	3,065	2,888	3,606	3,567	4,087	3,626	3,846	3,654	2,926	2,145	2,642	3,277
Cattle	3,146	2,903	3,716	3,985	4,103	3,639	4,496	4,445	3,942	2,889	3,559	3,711

Source: Compiled from: FAOSTAT Data 2-12-2021 Cattle Liveweight Data <fao.org>

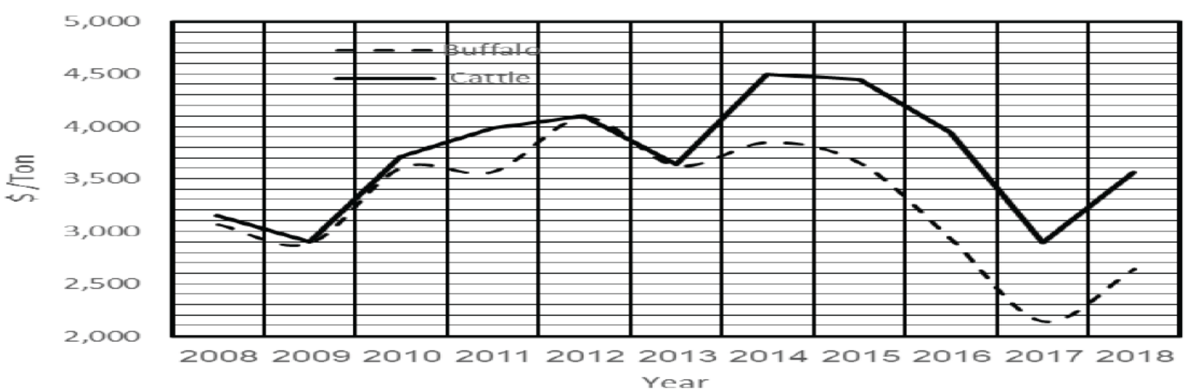

Figure 3: Buffalo and cattle male live weight price.

Source: Table **5**.

fattened buffalo males. The higher price per ton liveweight of Cattle bulls liveweight than buffalo males sold (Table **5**) and (Figure **3**) would also reflect the higher demand for better quality meat cattle feedlot males of faster daily gain liveweight. The annual average farm price/ton (2008- 2018) was about $3,277 for buffalo bulls and $3,711 for cattle bulls sold. It should be mentioned that the decrease in buffalo and cattle bull's price over the period (2012- 2017) was due to the socioeconomic changes associated with the Arab Spring revolutionary movement which, started on 25th of 2011 in Egypt, even though the prices have returned to increase trend after 2017 (Table **5** and Figure **3**). In 2018 the cattle bull's 1-kg liveweight farm price surpassed buffalo price by about $1000. In addition, the apparent higher off-take rate of slaughtered buffalo of 31% than cattle of 24% was not an efficiency measure. This is because most buffalo males are sold as veal at 2-3 months old before weaning to save buffalo milk of higher price than cow milk in Egypt and save feeds for dairy animals and fattening cattle males of faster daily live weight gain [11].

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