

Modeling Poultry Physiological Parameters using Neural Networks

H. Anwar Ahmad, *PhD, MBA, MCIS*
Associate Professor
JACKSON STATE UNIVERSITY

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My Journey

- BSc Animal Husbandry
- MSc Animal Nutrition
- PhD Animal Science
- Post Doc Poultry Nutrition Modeling
- MBA
- MCIS
- Computational Modeling Tuskegee Univ
- Biostatistics JSUMS

My Journey

Two Research Projects:

- NIH Biostatistics Support Unit
- USAID [Biostatistics Consulting Center](#)

Broiler Growth Modeling



Broiler Growth Modeling

- Determination of optimal nutrient requirements in broiler requires an adequate description of bird growth and body composition using growth curves.
- One-way to calculate nutrient requirements and predict the feed intake of growing broilers needs to start with the understanding of the genetic potential.



Broiler Growth Modeling

- Typically nutritionists takes one nutrient at a time and keeping everything else constant monitor the body growth over certain period of time on a graded level of that particular nutrient, ignoring overall system approach and thus missing the bigger picture.



Gompertz non linear Regression Equation

- $W = A \exp[-\log(A/B)\exp(-Kt)]$.
- W is the weight to age (t) with 3 parameters:
- A is asymptotic or maximum growth response,
- B is intercept or weight when age (t) = 0,
- K is rate constant.]



Broiler Growth Modeling

- The current research project is a step towards a holistic system approach.
- Using all the available information from published literature, simulated and experimental data artificial intelligence (AI) models were developed using body growth for future energy requirements in broilers.

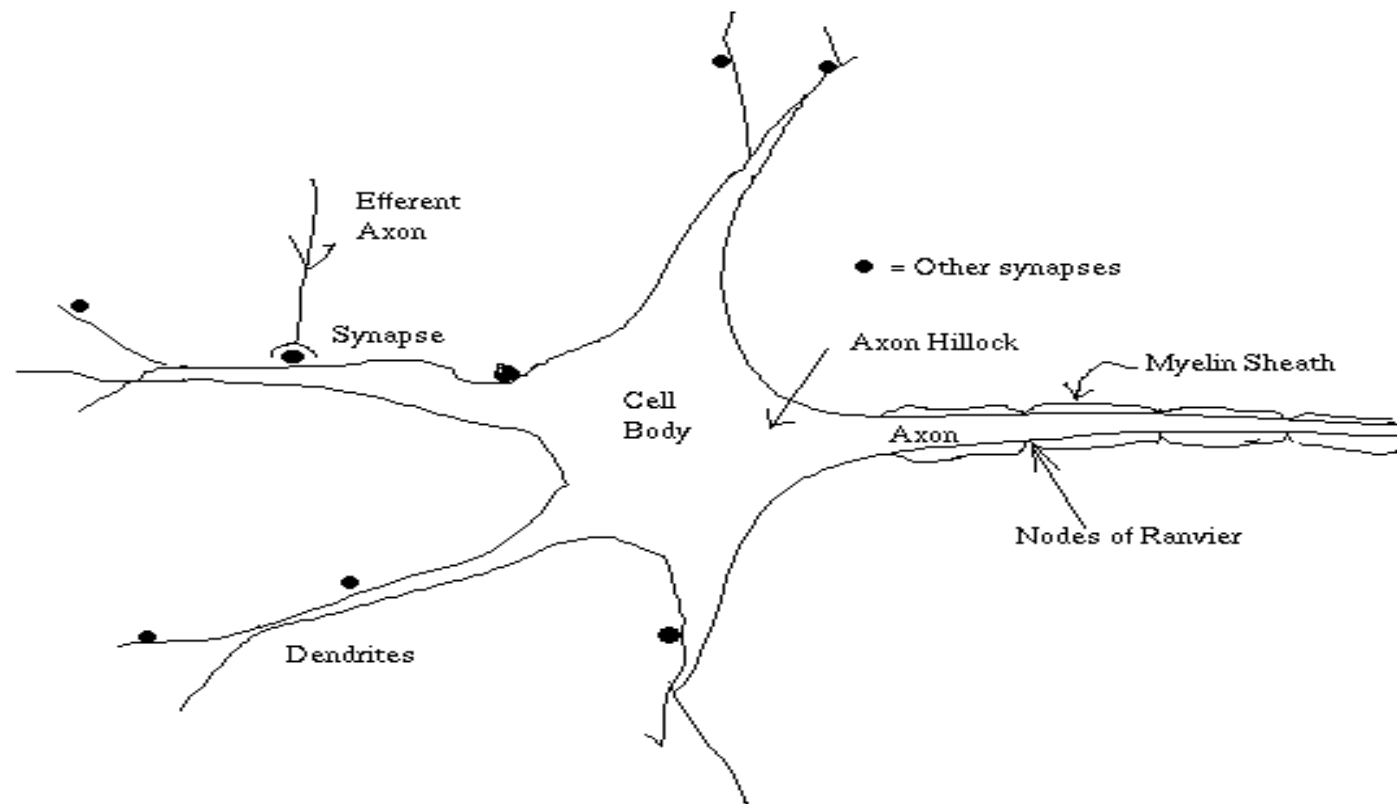


Neural Networks

- A neural network is a mathematical model of an information processing structure that is loosely based on the working of human brain.
- An artificial neural network consists of large number of simple processing elements connected to each other in a network.



Neural Networks-Neurons

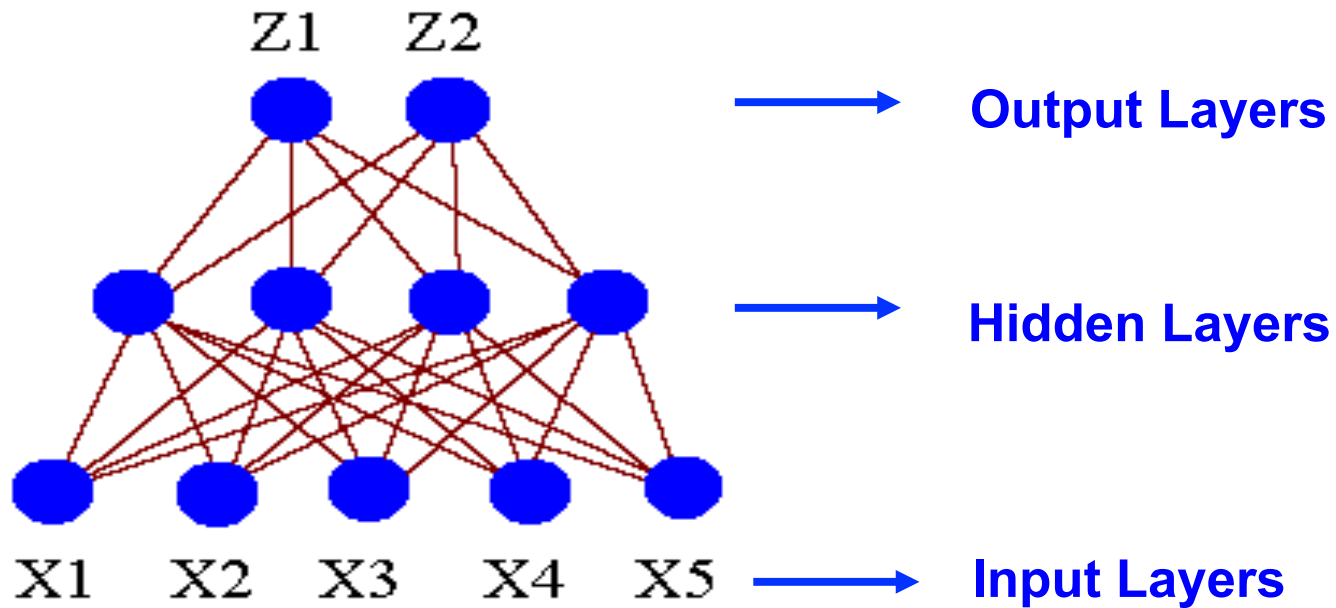


Neural Network - A biological view

- Human brain is highly complex, non-linear, parallel and efficient information processing system.
- **Neurons** (10 billion) - structural constituents of the brain.
- **Synapses** (60 billion) - massive interconnections that impose excitation or inhibition.
- **Plasticity** - developing nervous system adapts to environment.
- **Axons** - transmission lines
- **Dendrites** - receptive zones



Schematic View of Artificial Neural Network



Data Collection

- Average daily body weights of 25 male broiler chicks (Ross x Ross 308) from day 1- day 70, were selected from a recently published report (Roush *et al.*, 2006).
- These averages were converted into 14 interval classes of 5 days each, with means and standard deviations.
- These five day-interval classes of broiler growth reflect accurate growth patterns and curves in broilers.



5-D Average Bwt Interval	Mean	Standard Deviation	95% confidence interval	Lower 95% CI	Upper 95% CI	RiskNormal Distribution
1	55.20	14.46	6.34	48.86	61.54	55.20
2	138.20	38.80	17.01	121.19	155.21	138.20
3	312.20	70.95	31.09	281.11	343.29	312.20
4	588.80	104.71	45.89	542.91	634.69	588.80
5	945.40	120.20	52.68	892.72	998.08	945.40
6	1354.00	135.07	59.20	1294.80	1413.20	1354.00
7	1826.40	162.98	71.43	1754.97	1897.83	1826.40
8	2334.60	166.98	73.18	2261.42	2407.78	2334.60
9	2828.60	147.32	64.57	2764.03	2893.17	2828.60
10	3292.40	152.40	66.79	3225.61	3359.19	3292.40
11	3765.80	137.95	60.46	3705.34	3826.26	3765.80
12	4159.80	110.91	48.61	4111.19	4208.41	4159.80
13	4488.20	94.15	41.26	4446.94	4529.46	4488.20
14	4708.80	32.87	14.40	4694.40	4723.20	4708.80

Data Simulation

- The 14 means and standard deviations were used to simulate broiler growth data from day 1 to day 70, with Normal distribution of @Risk software (Palisade Corporation).
- Six simulations with one thousand iterations each were performed.



Data Manipulation and Simulation

- On each 14 interval classes of 5days, 100 data points were randomly drawn for a total of 1400 observations, representing 20 observations for each day up to 70 days.
- Only 50 days data were used for this research and were arranged in one row of spreadsheet to determine training examples for neural network training.



Neural Networks Training

- Out of 1400 data points, 750 training examples (epoch) for NN training were generated



Neural Networks Training

- Out of 1400 data points, 750 training examples (epoch) for NN training were generated.
- Starting from the day one, the first four body weight observations were used as inputs while the fifth day body weight observation were used as output, to constitute one training example (epoch).



Neural Networks Training

- The second training example consisted of second, third, fourth, and fifth observations of day one body weight, as inputs, while the sixth observation of day one as output.
- There were a total of 750 such examples (epoch) generated with the simulated data.



Neural Networks Testing

- For the NN testing the same procedure of epoch generation was applied.
- However, instead of simulated data, the original body weight data was used for a total of 50 epoch.

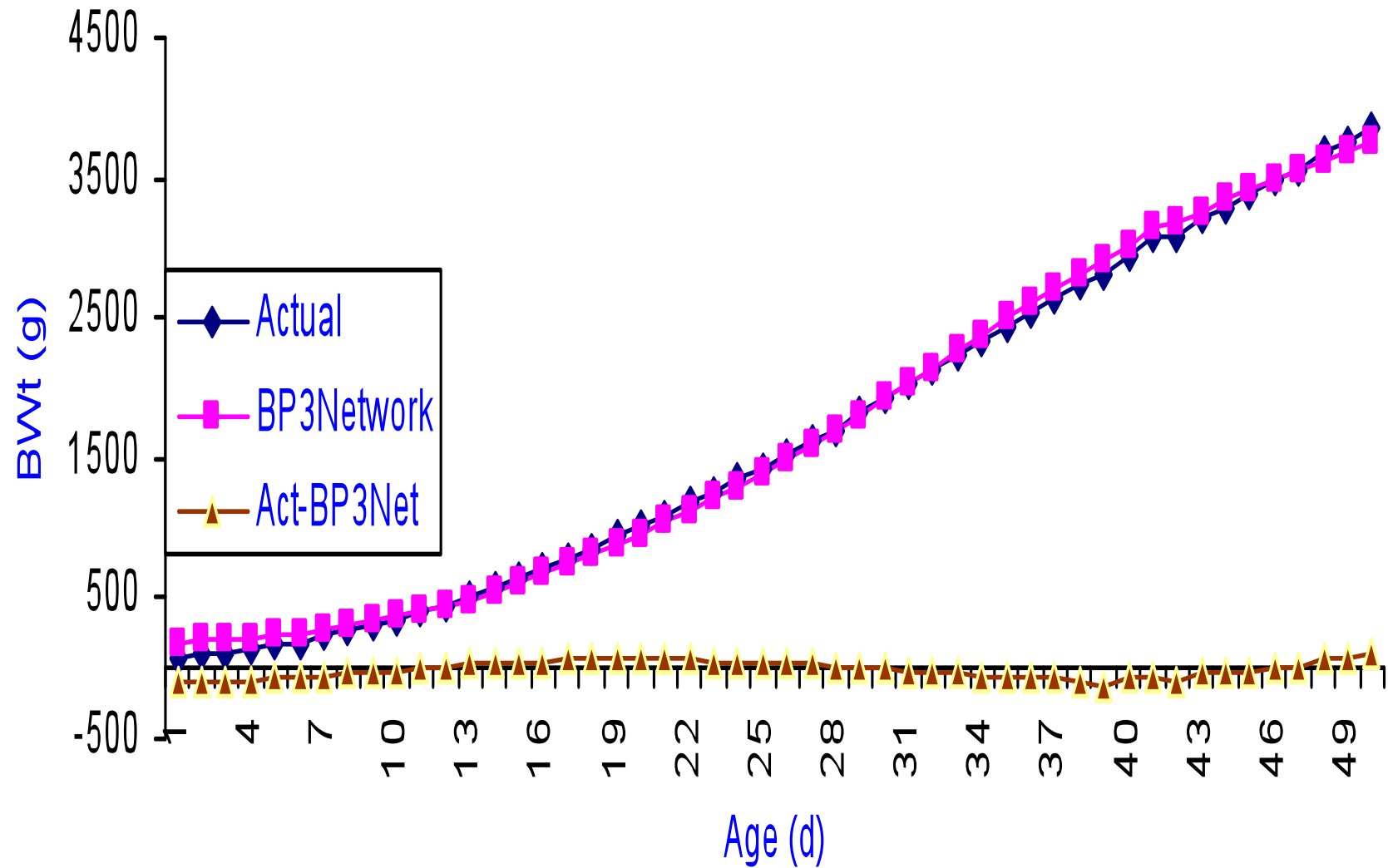


Age(d)	BW(g)	I1	I2I	I3	I4	O	Epoch
1	43	43	43	51	62	77	1
2	43	43	51	62	77	93	2
3	51	51	62	77	93	113	3
4	62	62	77	93	113	134	4
5	77	77	93	113	134	159	5
6	93	93	113	134	159	192	6
7	113	113	134	159	192	227	7
8	134	134	159	192	227	265	8
9	159	159	192	227	265	308	9
10	192	192	227	265	308	355	10
11	227	227	265	308	355	406	11
12	265	265	308	355	406	460	12
13	308	308	355	406	460	520	13
14	355	355	406	460	520	586	14
15	406	406	460	520	586	654	15
16	460	460	520	586	654	724	16
17	520	520	586	654	724	796	17
18	586	586	654	724	796	868	18
19	654	654	724	796	868	944	19
20	724	724	796	868	944	1018	20
21	796	796	868	944	1018	1101	21
22	868	868	944	1018	1101	1185	22
23	944	944	1018	1101	1185	1270	23
24	1018	1018	1101	1185	1270	1349	24
25	1101	1101	1185	1270	1349	1438	25
26	1185	1185	1270	1349	1438	1528	26
27	1270	1270	1349	1438	1528	1632	27
28	1349	1349	1438	1528	1632	1704	28
29	1438	1438	1528	1632	1704	1830	29
30	1528	1528	1632	1704	1830	1936	30
31	1632	1632	1704	1830	1936	2030	31
32	1704	1704	1830	1936	2030	2122	32
33	1830	1830	1936	2030	2122	2230	33
34	1936	1936	2030	2122	2230	2335	34
35	2030	2030	2122	2230	2335	2442	35
36	2122	2122	2230	2335	2442	2544	36
37	2230	2230	2335	2442	2544	2650	37
38	2335	2335	2442	2544	2650	2739	38
39	2442	2442	2544	2650	2739	2801	39
40	2544	2544	2650	2739	2801	2942	40
41	2650	2650	2801	2942	3011	3089	41
42	2739	2739	2801	2942	3011	3089	42
43	2801	2801	2942	3011	3089	3207	43
44	2942	2942	3011	3089	3207	3295	44
45	3011	3011	3089	3207	3295	3395	45
46	3089	3089	3207	3295	3395	3476	46
47	3207	3207	3295	3395	3476	3568	47
48	3295	3295	3395	3476	3568	3706	48
49	3395	3395	3476	3568	3706	3770	49
50	3476	3476	3568	3706	3770	3867	50

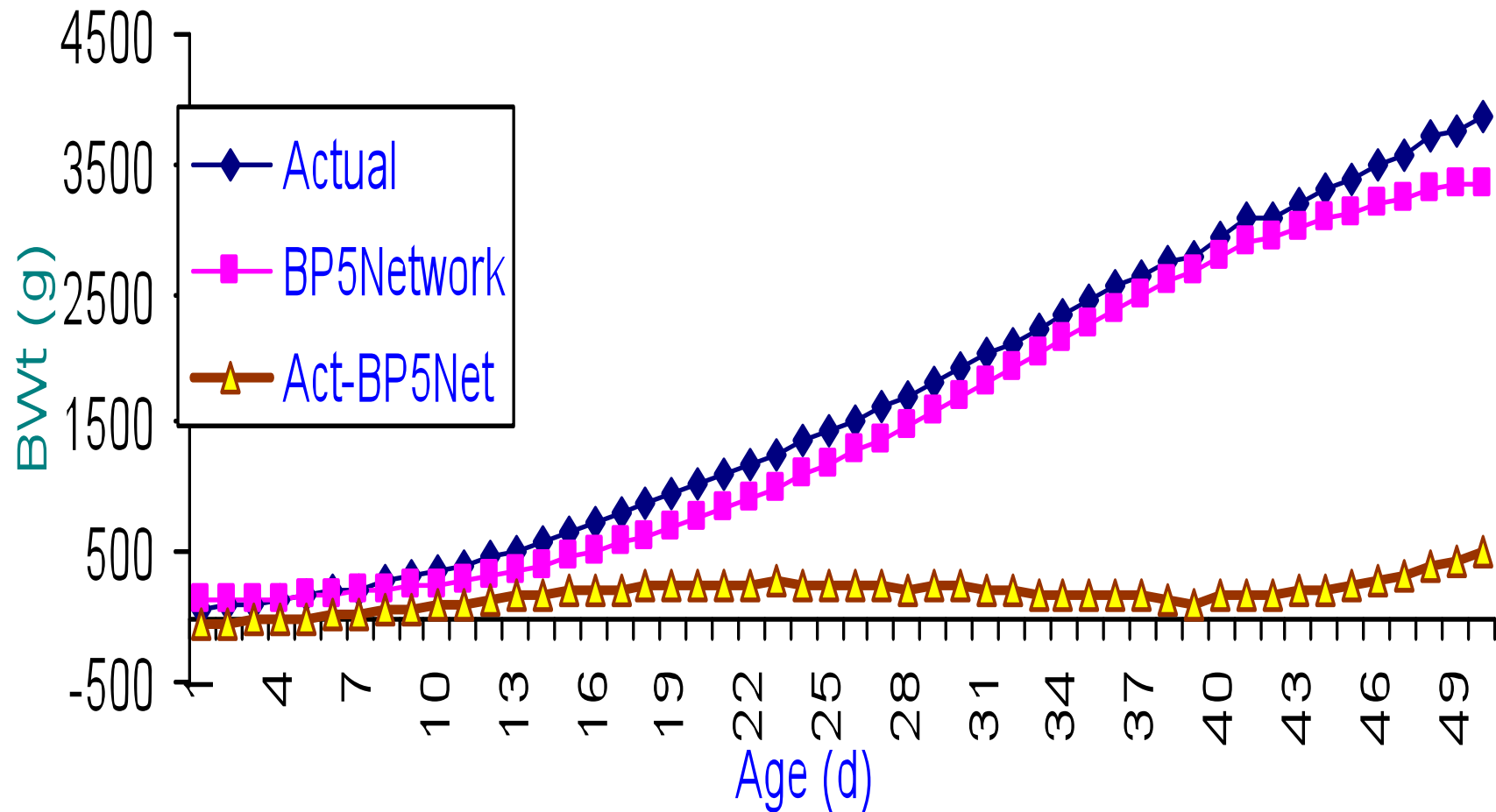
Results- Neural Networks Comparisons

Output:	BP3	Output:	BP5	Output:	Ward
R squared	0.998	R squared	0.967	R squared	0.973
r squared:	0.998	r squared:	0.994	r squared:	0.9986
Mean squa	3514	Mean squa	47376	Mean squa	38949
Mean abso	51.198	Mean abso	190.369	Mean abso	182.532
Min. absol	0.453	Min. absol	0.058	Min. absol	35.495
Max. absol	118.192	Max. absol	516.575	Max. absol	415.5
Correlation	0.999	Correlation	0.997	Correlation	0.9993
Percent wit	64.000	Percent wit	4.000	Percent wit	0
Percent wit	20.000	Percent wit	34.000	Percent wit	28
Percent wit	2.000	Percent wit	24.000	Percent wit	38
Percent wit	2.000	Percent wit	32.000	Percent wit	12
Percent ove	12.000	Percent ove	6.000	Percent ove	22

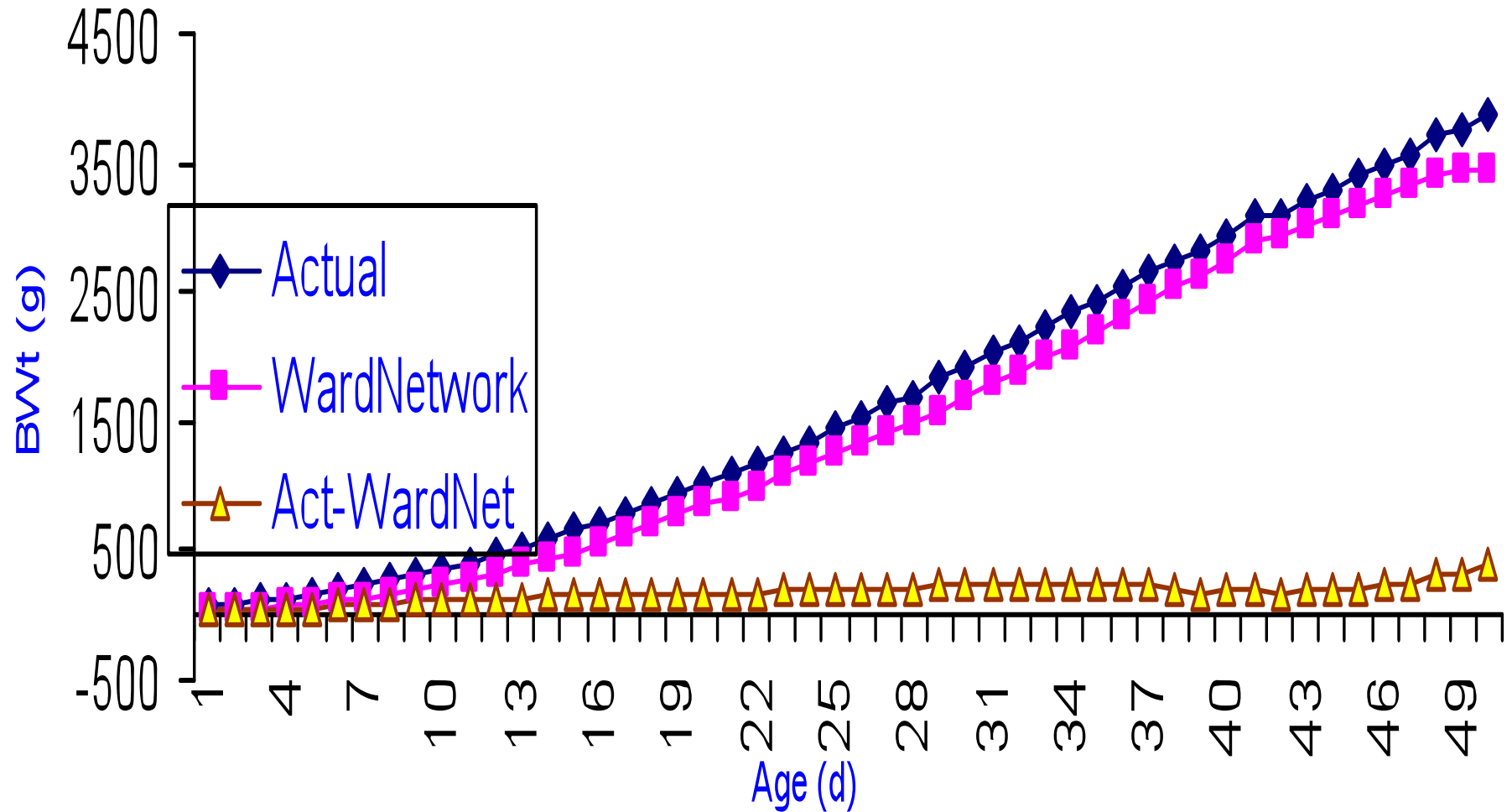
BP3- NN Body Weight Prediction with Roush Test Data



BP5- NN Body Weight Prediction with Roush Test Data



Ward NN Body Weight Prediction with RoushTest Data



Conclusion

- A holistic system approach encompasses all aspects of the problem instead fragmented solution.
- Simulated approach is efficient and feasible once the underlying variables and parameters of the problem are clearly understood and defined.



Conclusion

- [Ahmad](#), H. A, 2009. Poultry Growth Modeling using Neural Networks and Simulated Data. J. Appl. Poultry Res. 18:440-446
- [Ahmad](#), H.A., M. Mariano, 2006. Comparison of Forecasting Methodologies using Egg Price as a Test Case. Poultry Science 85:798-807



Conclusion

- BP3 NN gives the best prediction lines with near perfect R^2 (0.998) value out of all the NN architecture utilized.
- NN modeling approach is an efficient and better alternative to its traditional statistical counterparts.
- Further research on energy and amino acid modeling will enhance our understanding of these modeling approaches.



Egg Production Modeling



Egg Production Modeling

Mathematical and Stochastic Egg Production Models

- Compartmentalization model (Grossman and Koops, 2001)
- Very complex
- Stochastic model (Alvarez and Hocking, 2007)
- Require too many variables to determine egg production.
- Impractical under most commercial situations.



Data Collection

- Average weekly egg production data of 240 layers from 22 US commercial strains were graciously provided by David A. Roland of Auburn University.
- The data was collected in three phases:
wk 21-36; wk 37- 52; wk 53-66.
- Daily egg production data of 22 strains were computed into 7 day-hen production means and standard deviations.



Egg Production Curve

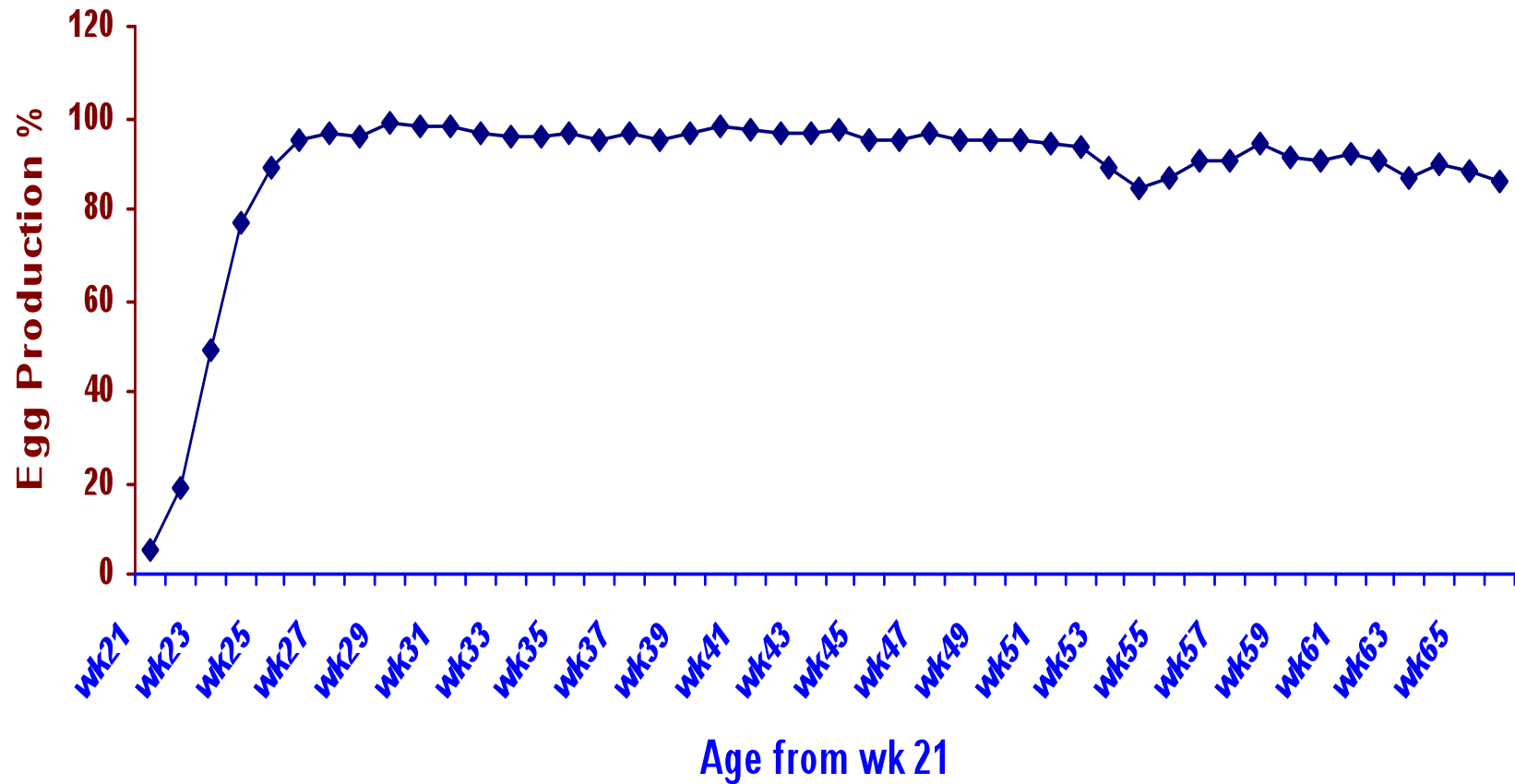
- Egg production curve in commercial layers follows a unique pattern:
- Production begins around 20 weeks of age starting slowly around 5%, increase weekly for the next 7-8 weeks until attain peak production of 95-97% around week 28.
- During next 8-10 weeks, egg production maintains a plateau around its peak production.
- Egg production during week 38-52 (phase II), slowly start declining.
- During phase III (wk 53-72), production declines further until it reaches a point of non-profitability, around 60%

Data Collection

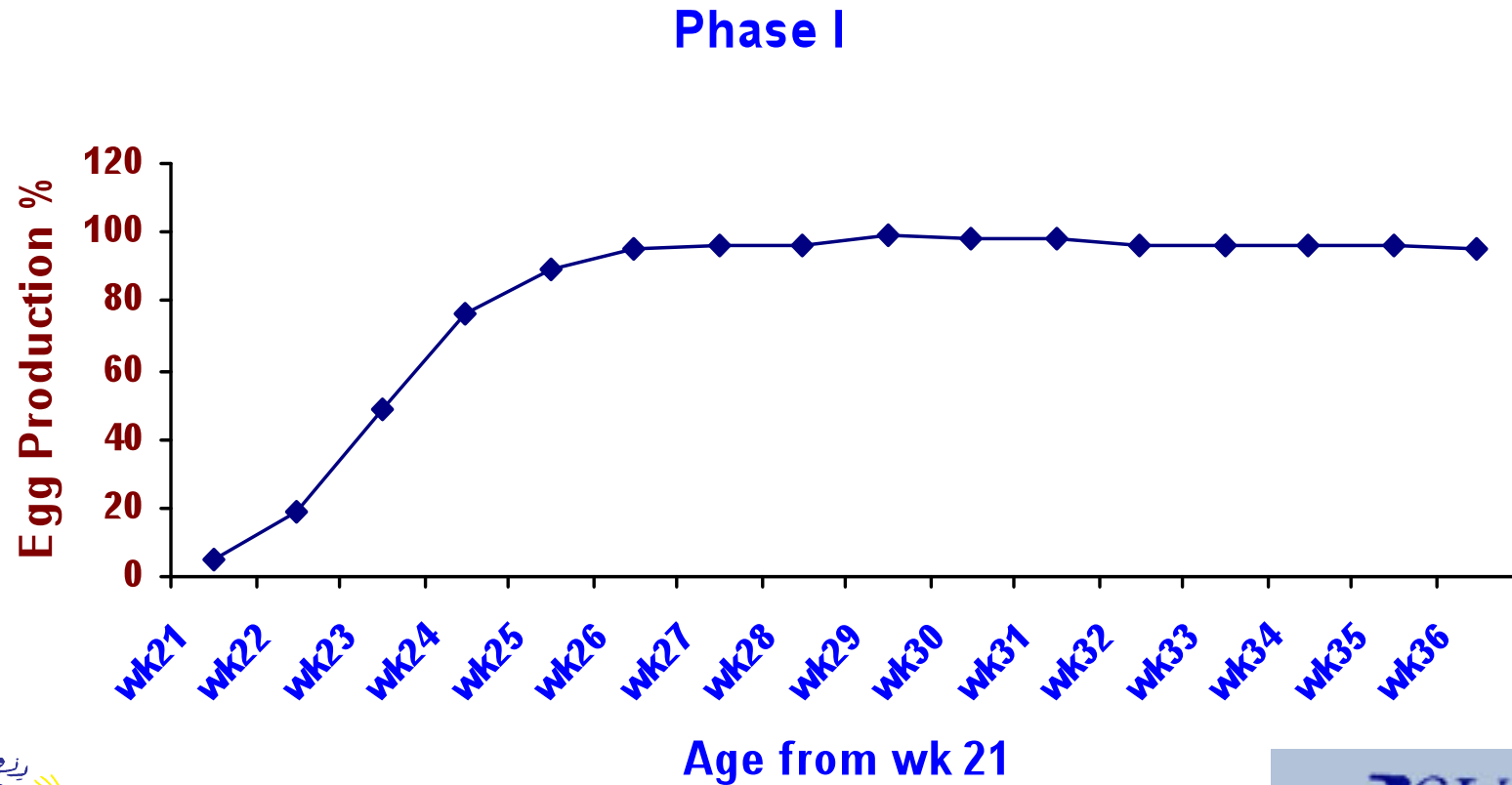
- The original data was used to map egg production curves in three different phases, compare curves among 22 commercial strains and compare strains laying white eggs with those laying brown eggs.



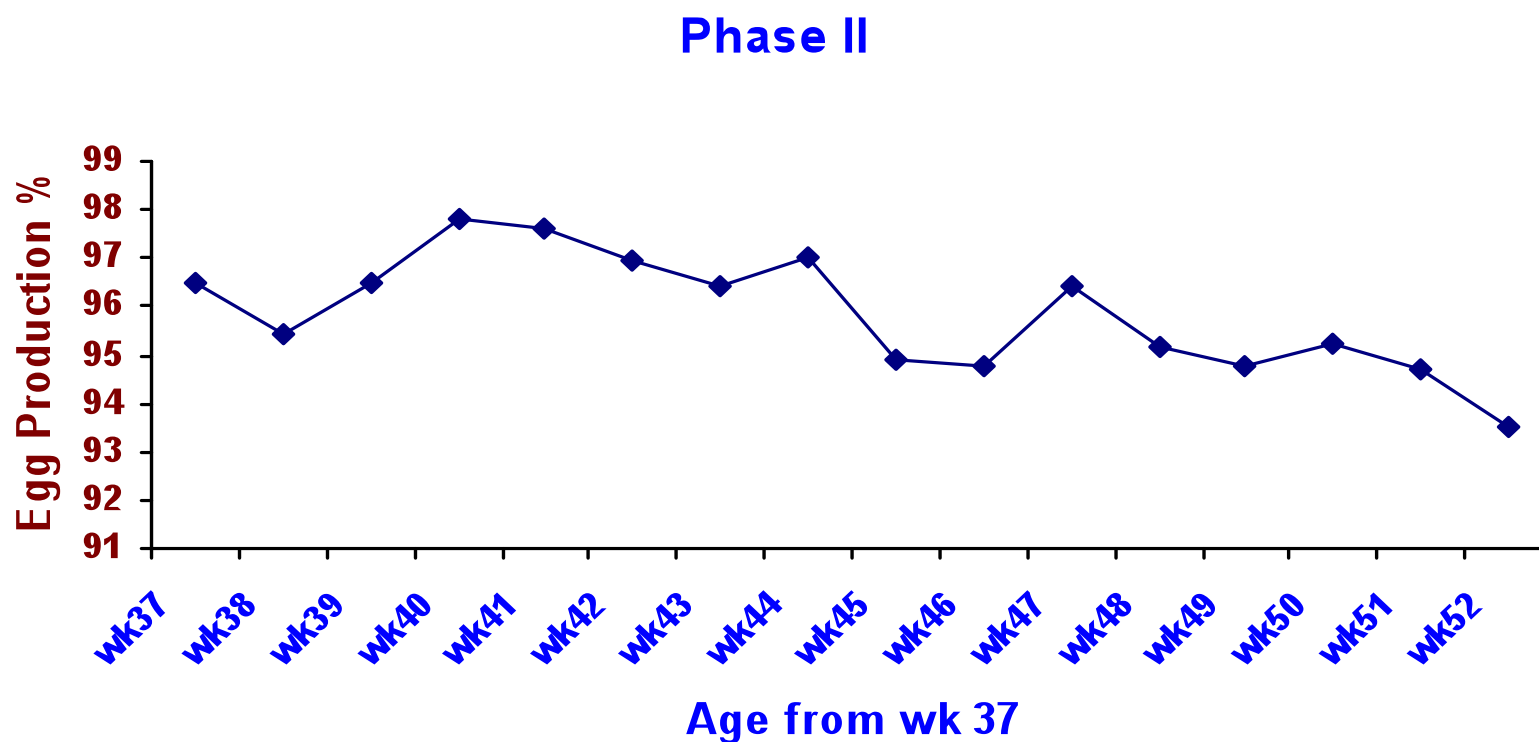
Egg Production Curve



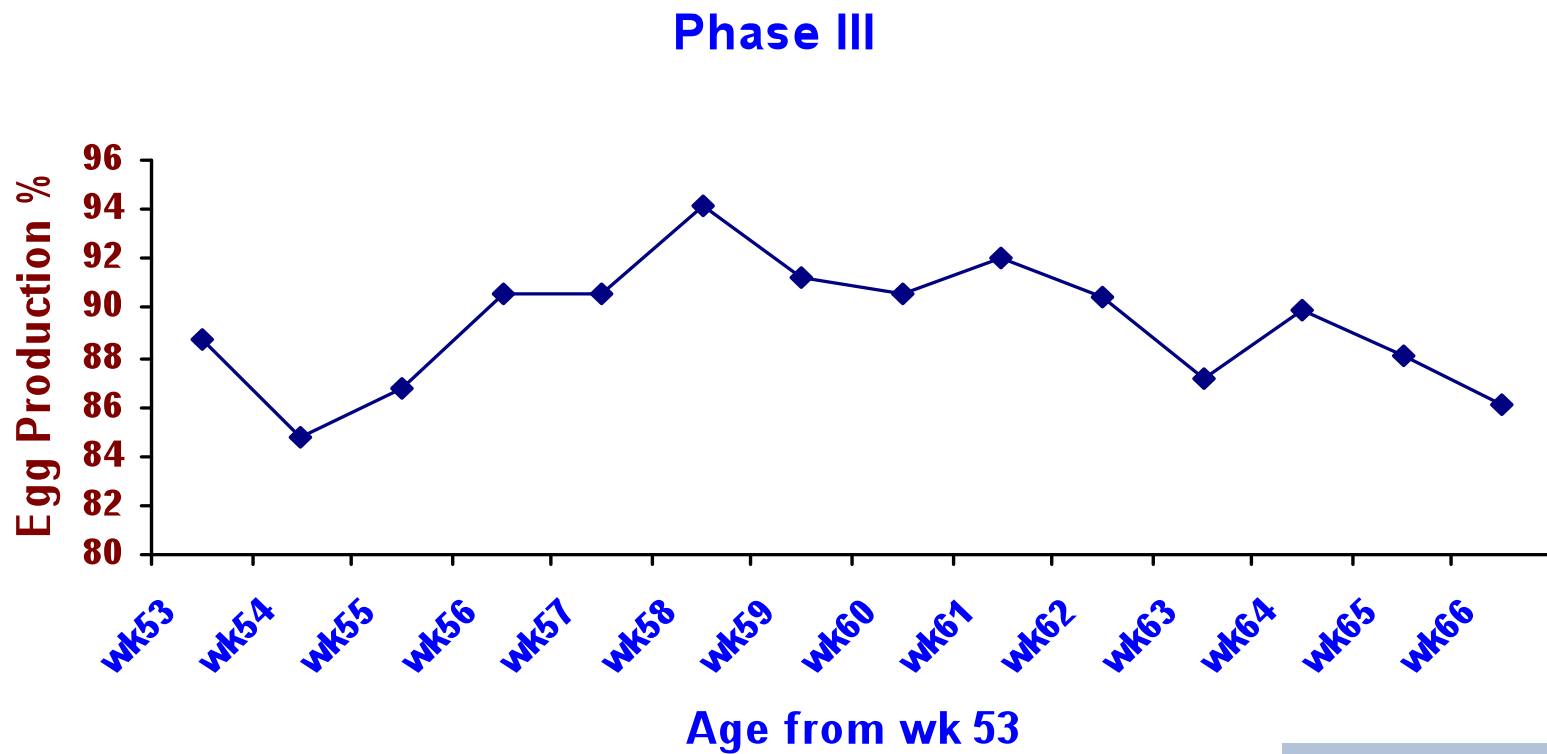
Egg Production Curve-phase I



Egg Production Curve-phase II

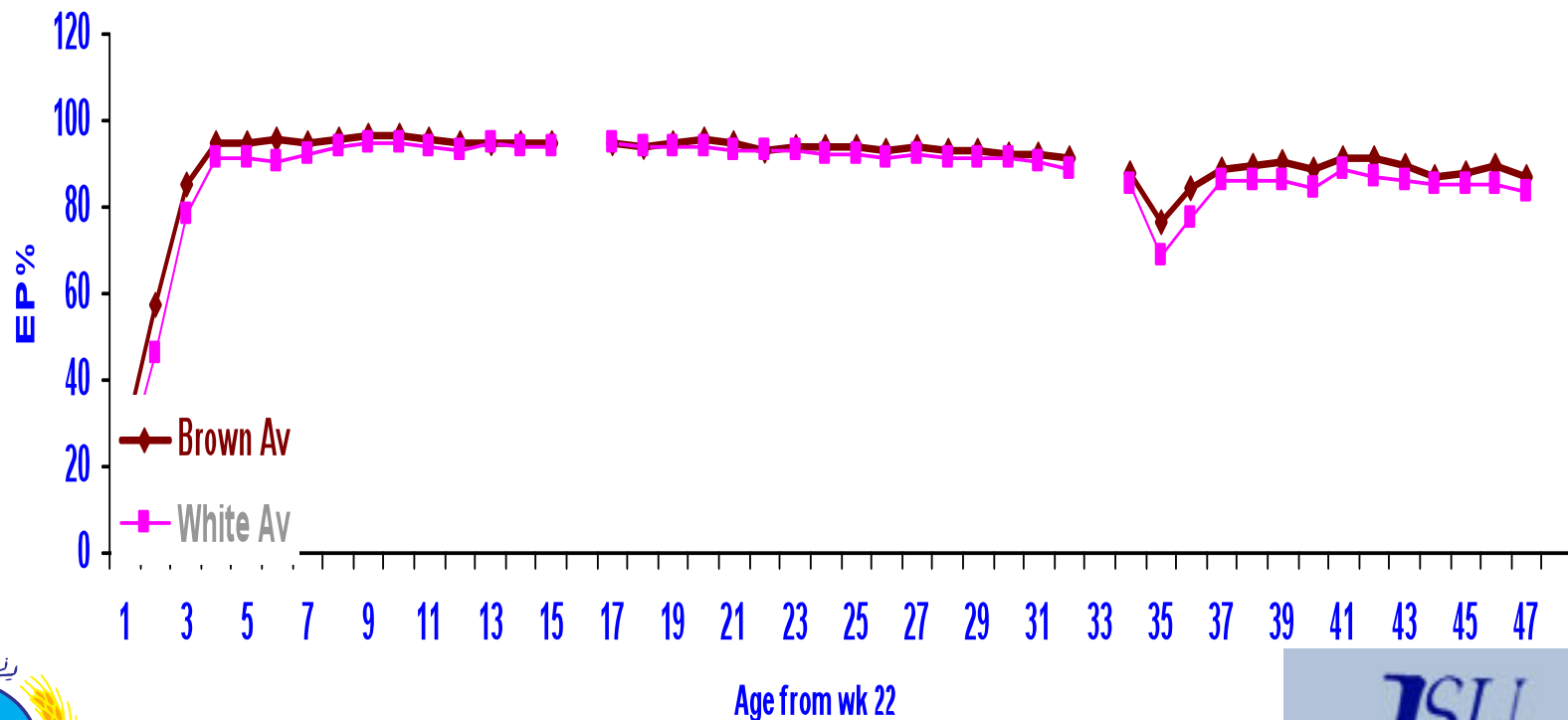


Egg Production Curve-phase III

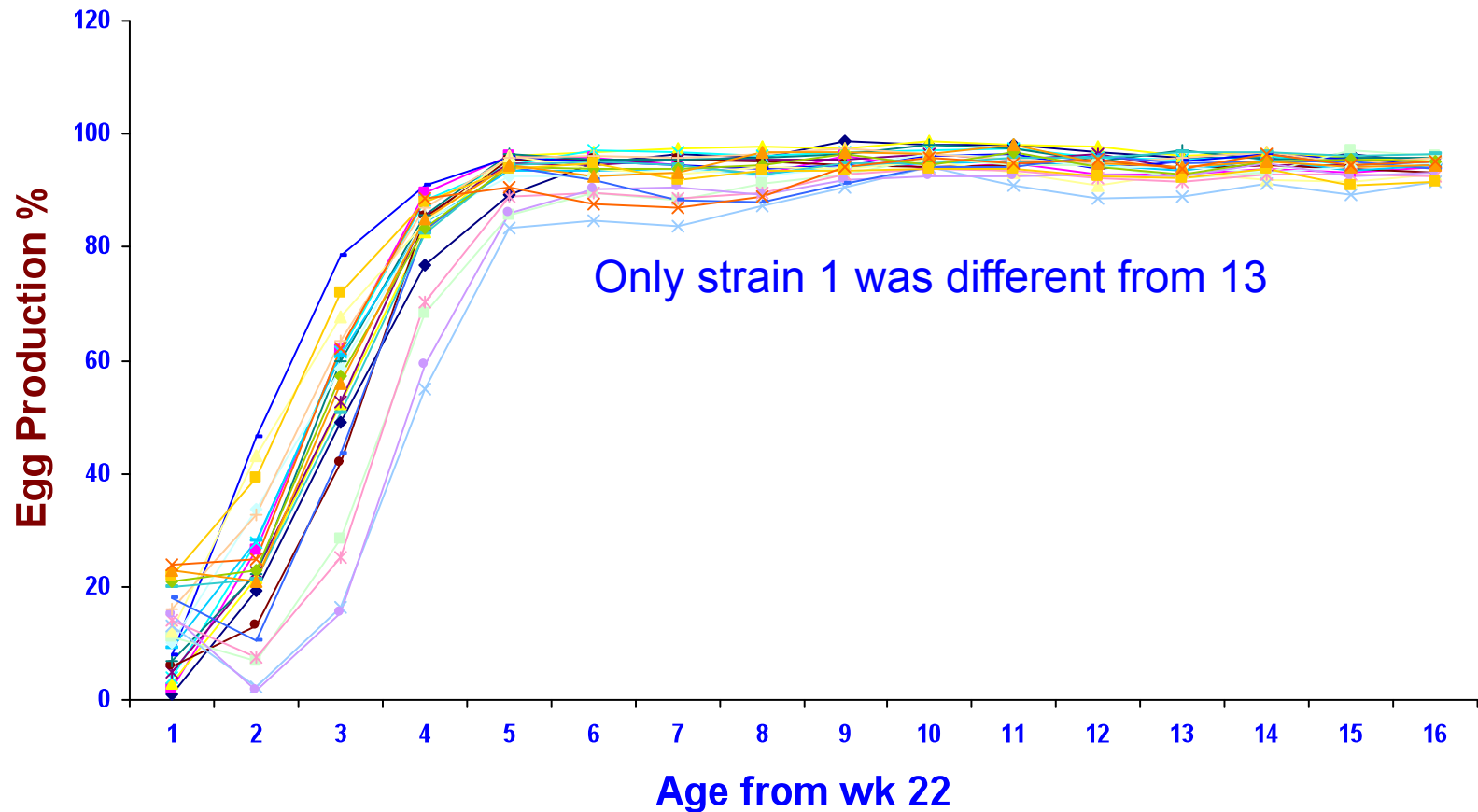


Comparative Egg Production

Brown vs. White Layers



Comparative Egg Production Curves of US Commercial Strains-phase I



Egg Production Modeling

- For the current project, data from one of the brown egg laying strain was chosen for simulation and training of neural networks.
- Mean weekly egg weights and standard deviations from wk 22-36 were computed.
- These parameters were fed into Normal Distribution of @Risk 4.0 software (Palisade Corporation).
- Six simulations with one thousand iterations each were performed.



Data Simulation and Manipulation

- On each 15 set of mean and standard deviation representing each week of production from week 22 to week 36, 20 data points were randomly drawn for a total of 300 observations, for training the neural networks.
- Similarly for testing the neural networks, ten random data points were drawn.



Data Simulation and Manipulation

- Each of 20 training and 10 test observations, for each week egg production, were arranged in one row of a spreadsheet to determine 105 neural network examples, respectively.



Neural Networks Training

- Starting from the wk 22, the first four egg production observations were used as inputs while the fifth observation were used as output, to constitute one training example (epoch).



Neural Networks Training

- The second training example consisted of second, third, fourth, and fifth observations of egg production, as inputs, while the sixth observation as output.
- There were a total of 105 such examples (epoch) generated with the simulated data.
- For the NN testing the same procedure of epoch generation was applied.



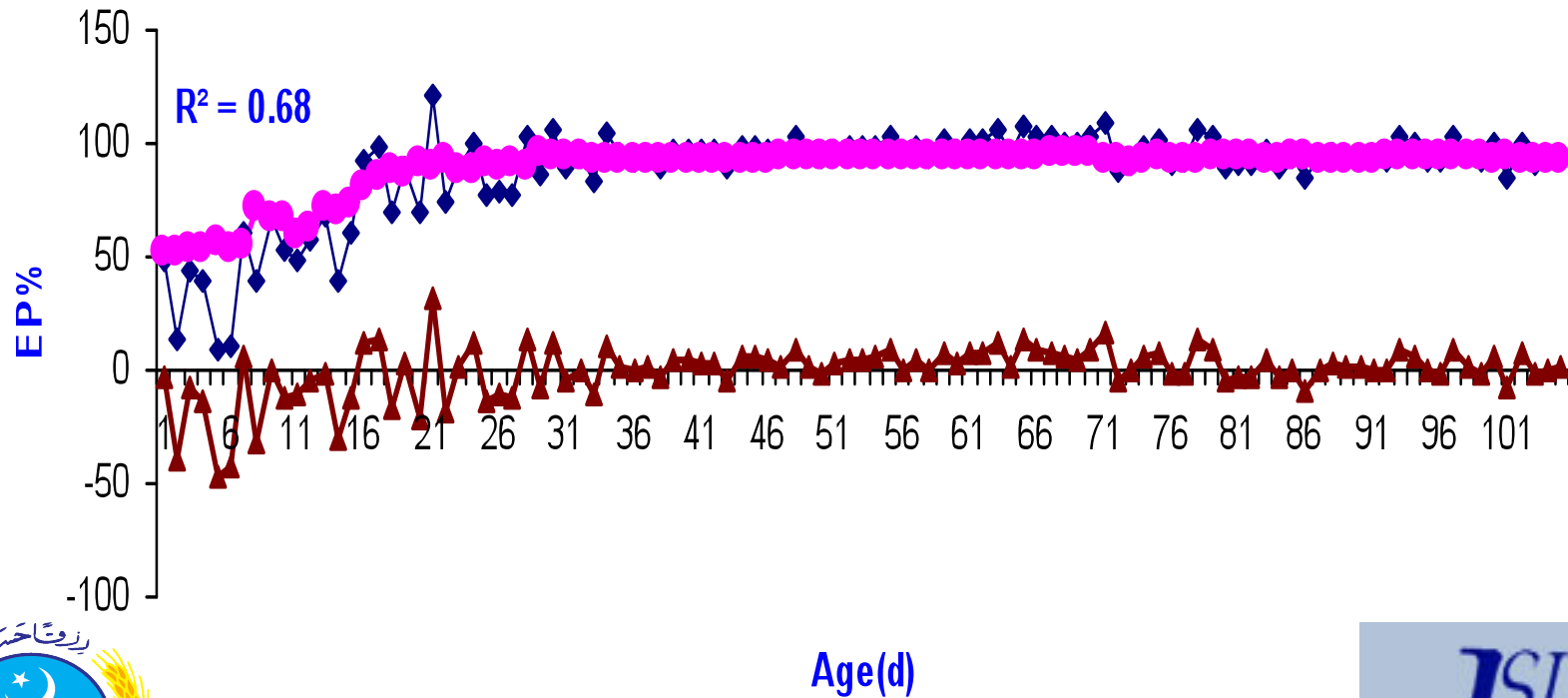
NN Examples (Epoch)

Age	Eg.	I1	I2	I3	I4	O
wk22	d1, epoch1	6.67	12.62	21.11	54.44	10.86
wk22	d2, epoch2	12.62	21.11	54.4	10.86	24.06
wk22	d3, epoch3	21.11	54.44	10.86	24.06	14.16
wk22	d4	54.44	10.86	24.06	14.16	19.67
wk22	d5	10.86	24.06	14.16	19.67	40.96
wk22	d6	24.06	14.16	19.67	40.96	54.21
wk22	d7	14.16	19.67	40.96	54.21	46.47
wk23	d8, epoch8	32.09	24.4	33.3	48.34	78.37
wk23	d9	24.4	33.3	48.34	78.37	47.75
wk23	d10	33.3	48.34	78.37	47.75	52.19
wk23	d11	48.34	78.37	47.75	52.19	73.86
wk23	d12	78.37	47.75	52.19	73.86	50.92
wk23	d13	47.75	52.19	73.86	50.92	49.9
wk23	d14	52.19	73.86	50.92	49.9	44.69

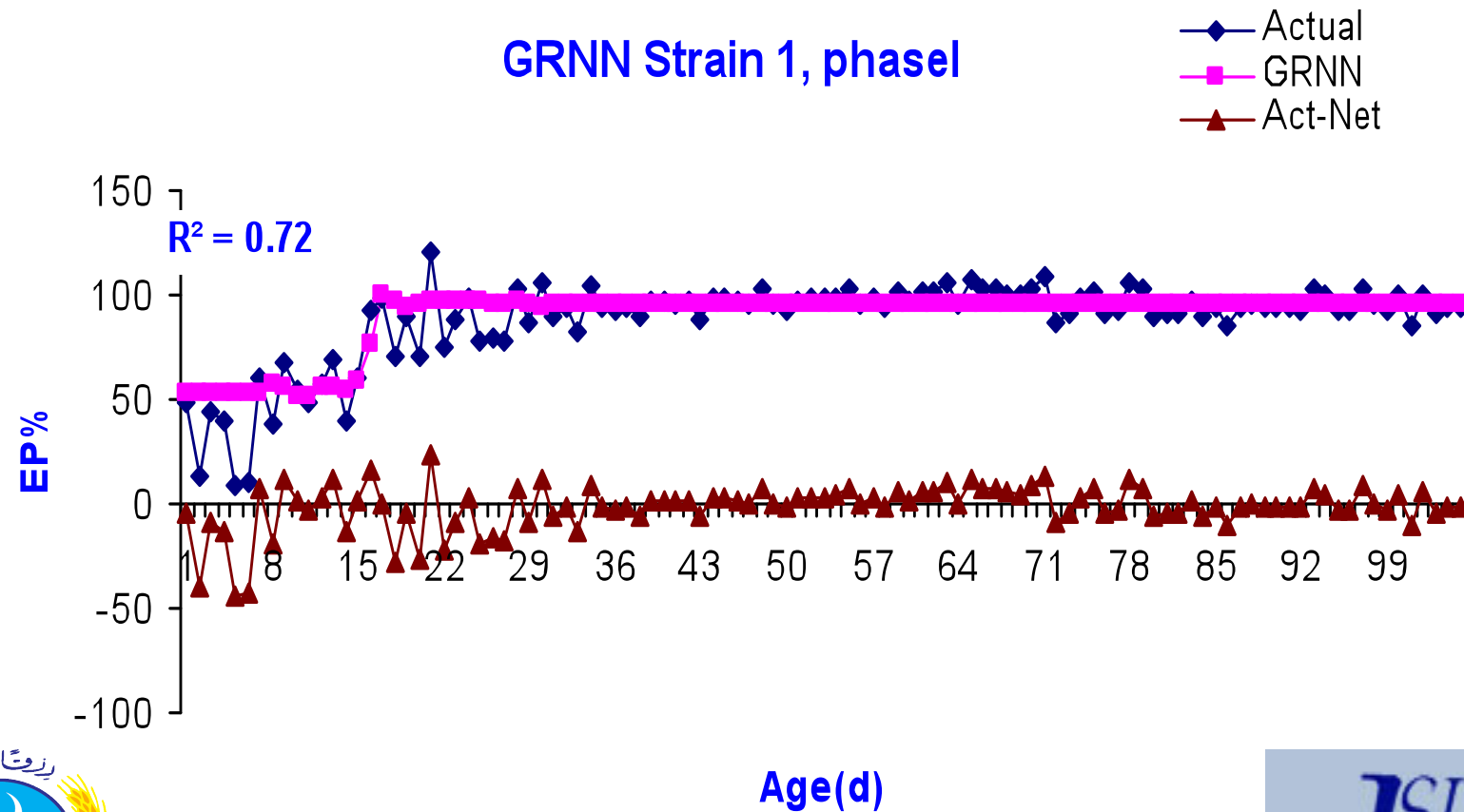
BP-3 Model

BP-3 NN Strain 1, phase 1

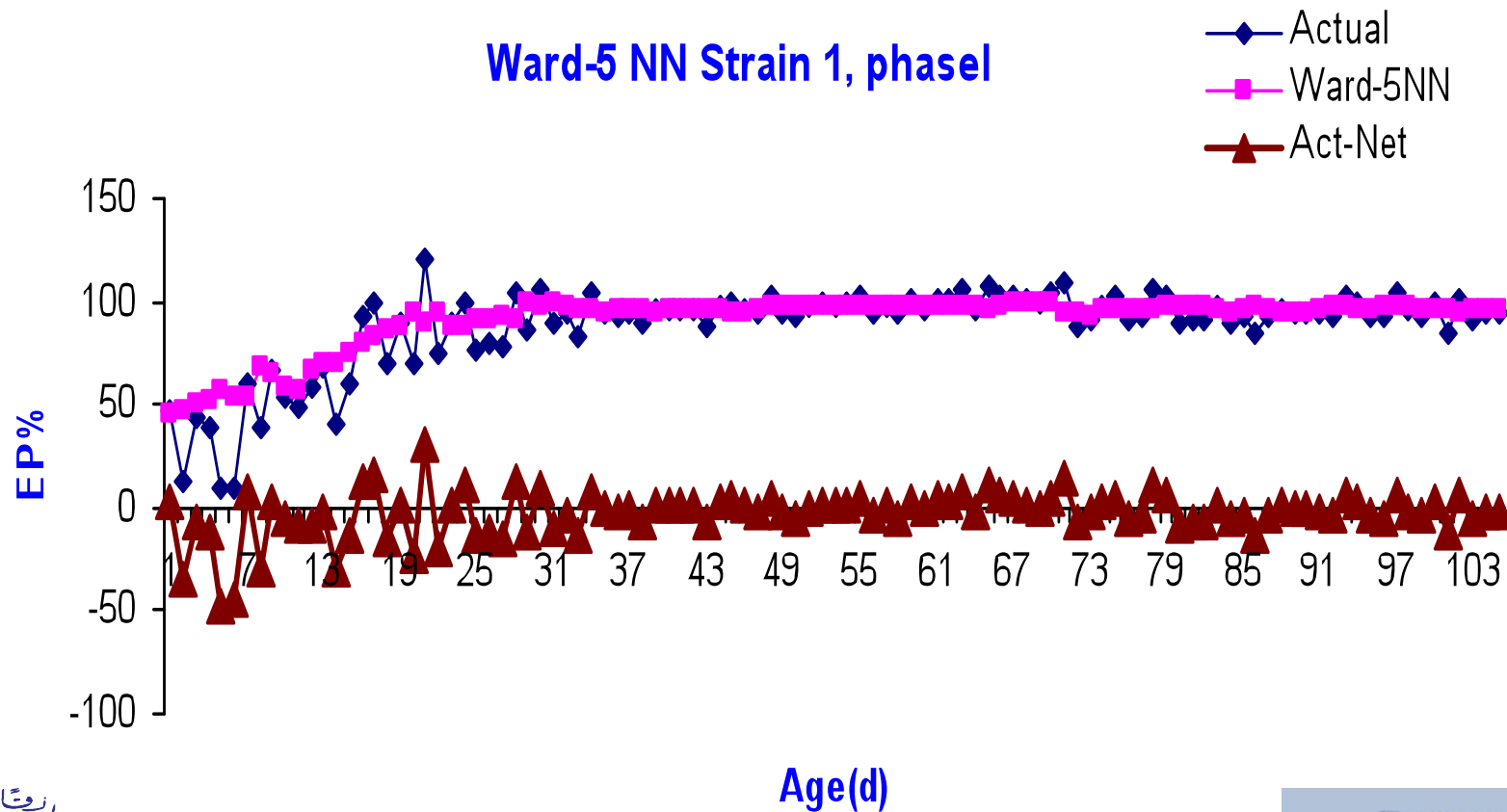
—◆— Actual
—●— BP-3NN
—▲— Act-Net



GRNN Model



WARD-5 Model

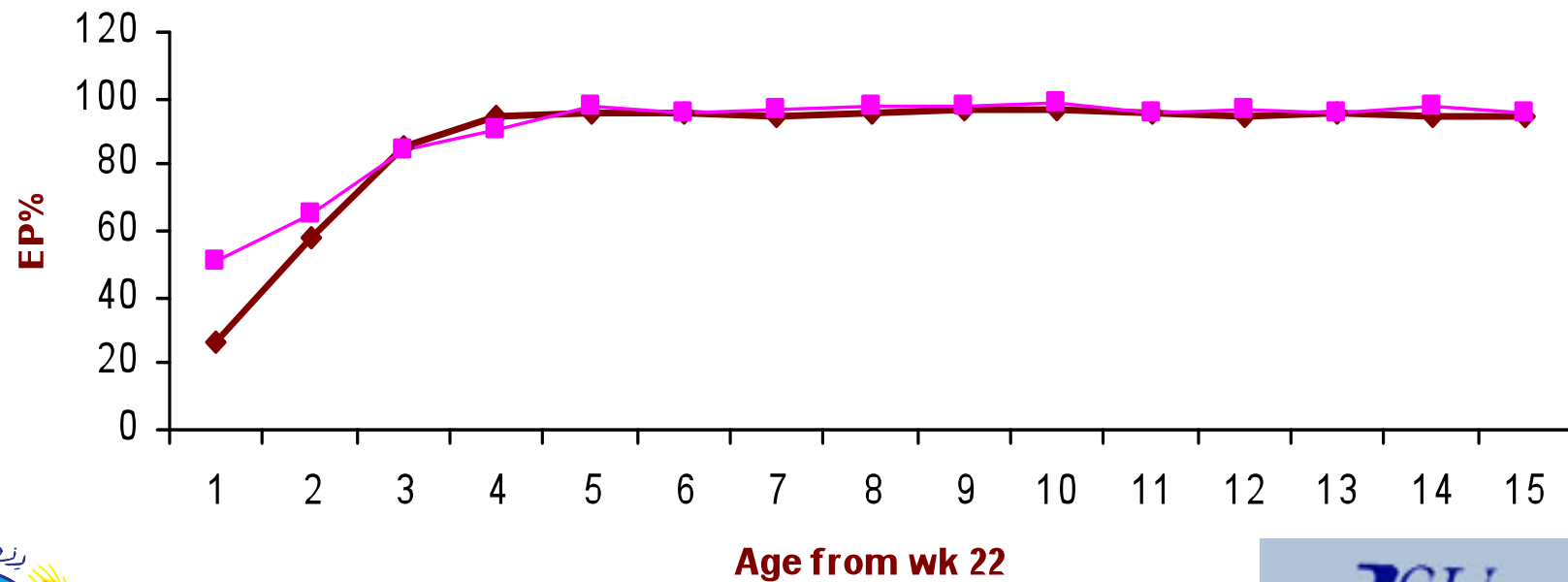


Results- Neural Networks Comparisons

Parameter	BP-3	GRNN	Ward-5
R squared:	0.681	0.715	0.697
r squared:	0.78	0.75	0.76
Mean squared error:	136.09	121.51	129.38
Mean absolute error:	7.81	7.28	7.40
Min. absolute error:	0.04	0.12	0.09
Max. absolute error:	46.54	43.54	48.40
Correlation coefficient r:	0.88	0.86	0.87
Percent within 5%:	45.71	49.52	50.48
Percent within 5% to 10%:	25.71	24.76	20.95
Percent within 10% to 20%:	16.19	15.24	18.10
Percent within 20% to 30%:	5.71	2.86	4.76
Percent over 30%:	6.67	7.62	5.71

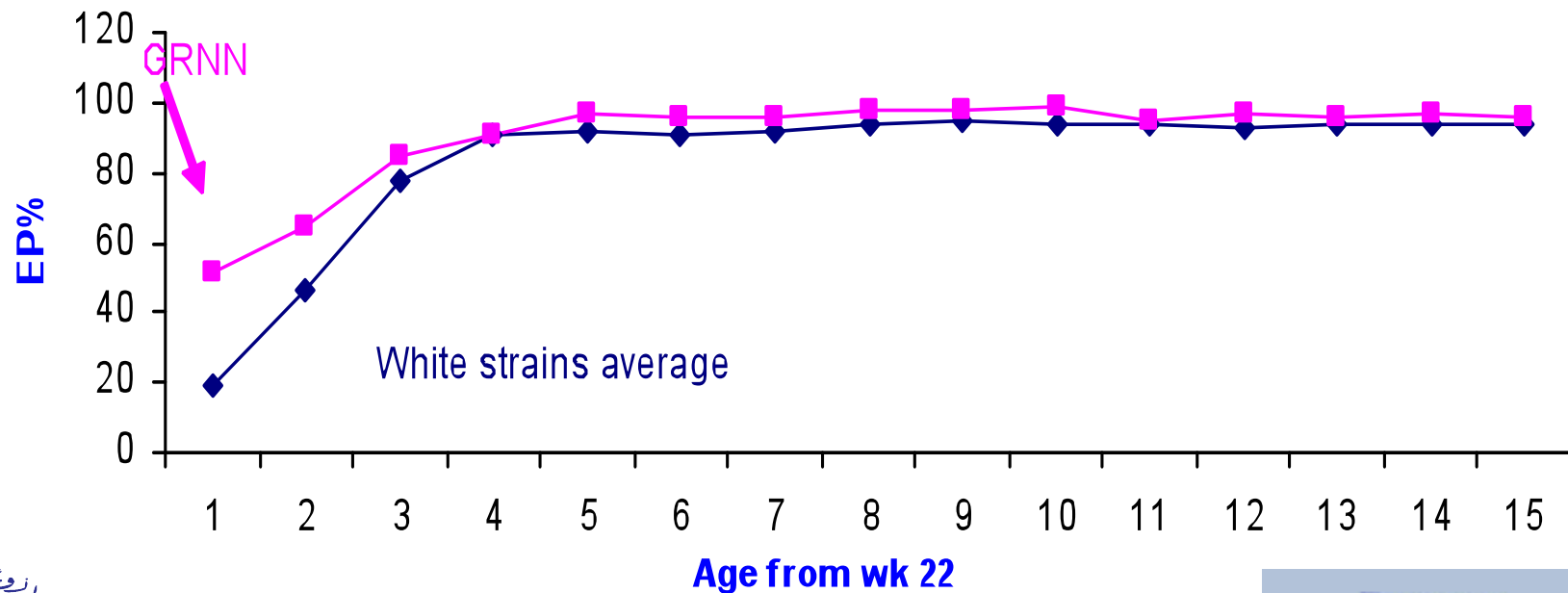
GRNN comparison with brown strains, phase I

GRNN Brown strains, phase I

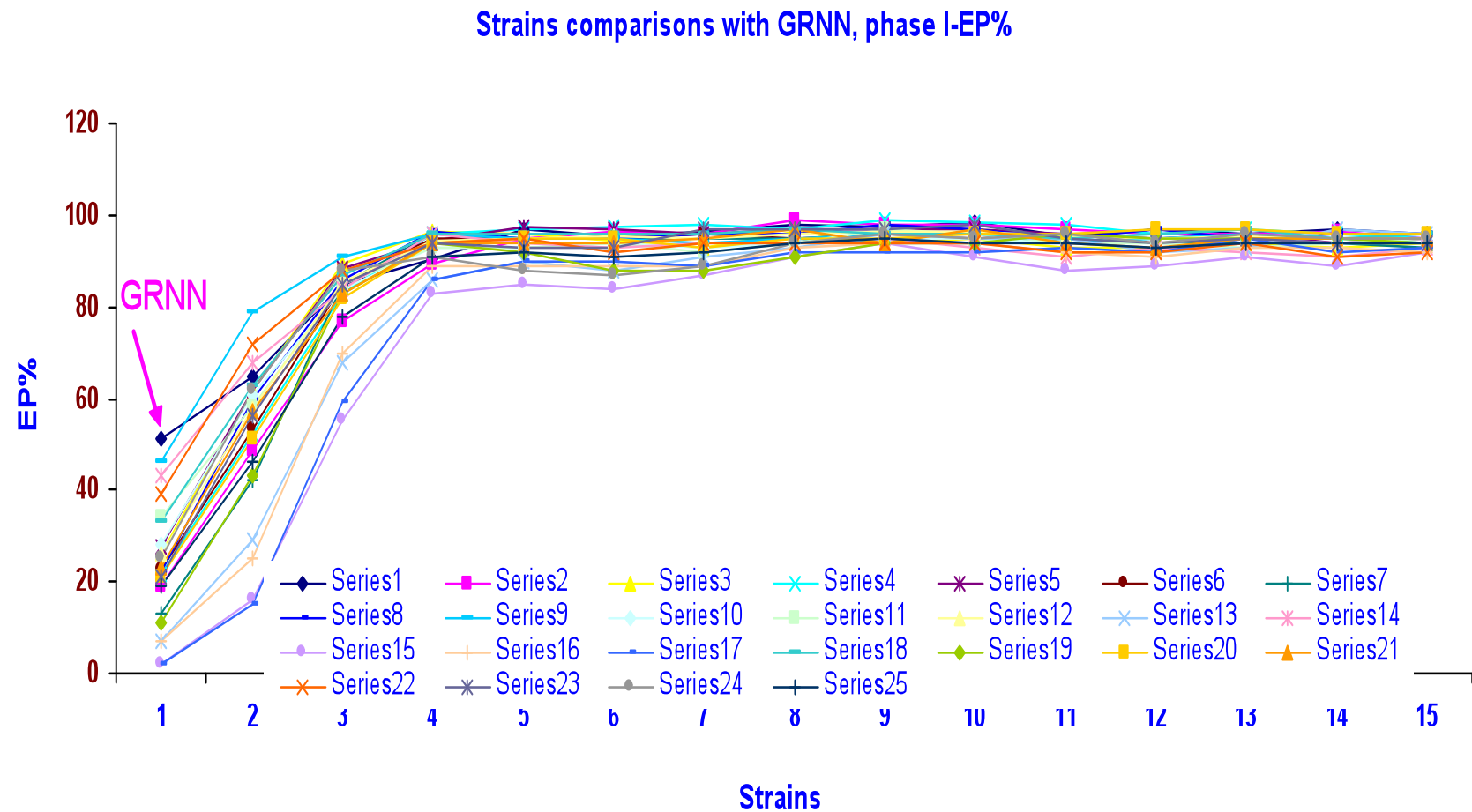


GRNN comparison with white strains, phase I

GRNN White strains, phase I



GRNN comparison with commercial strains, phase I



Conclusion

- Data simulation may offer a feasible alternative to expensive original data collection once the underlying variable's parameters are defined and understood.
- Compared to other mathematical and statistical models neural networks predicted egg production curve



Conclusion

- All three architect of NN produced comparable results in terms of R^2 that varied from 0.681 to 0.715.
- All the networks over predicted during the initial period when egg production was peaking.

Conclusion

- Once the initial over-prediction anomaly is corrected, NN modeling approach will be an efficient and superior to its traditional mathematical and statistical counterparts for egg production prediction.
- Further research on energy and amino acid modeling will enhance our understanding of these modeling approaches.



Conclusion

- **Ahmad**, H. A, 2010. Egg Production Forecasting: Determining efficient modeling approaches. Journal of Applied Poultry Research (under revision, manuscript ID JAPR-10-00266).

