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| **Artificial Neural Network Model to Predict Obrix and pH of Banana Based on Color Parameters**  Ferlando Jubelito Simanungkalit1,🖂, Hotman Manurung1  1 Department of Agricultural Product Technology, Faculty of Agriculture, HKBP Nommensen University, North Sumatera, INDONESIA. | |
| **Article History:**  Received : 29 February 2024  Revised : 19 April 2024  Accepted : 24 April 2024  **Keywords:**  *Artificial neural networks,*  *Color,*  *Computer vision system,*  *CVS,*  *RGB.*  Corresponding Author:  🖂 ferlandosimanungkalit@uhn.ac.id  (Ferlando Jubelito Simanungkalit) | **ABSTRACT** |
| *Artificial neural network (ANN) was used to predict internal quality parameters (oBrix and pH) of lady finger banana. This research consisted of three stages, namely: (1) capturing images of lady finger banana using a computer vision system; (2) measurement of oBrix and pH of the banana; (3) ANN architecture analysis using the Matlab R2019a application. The ANN architectural model consisted of 3 output models, namely: (1) oBrix values; (2) pH value; (3) oBrix and pH values. The ANN architecture analysis was carried out through two phases. Phase I consisted of 45 experimental units and phase II with 35 experimental units. The best ANN architecture to be used as a prediction model for oBrix and pH of golden banana fruit is ANN architecture model 3 with the number of neurons in the hidden layer = 3; activation function in hidden layer = logsig; activation function in the output layer = logsig; data transformation range 0 – 1; learning rate value = 0.01; learning algorithm = tradingda; with MSE (mean square error), MAE (mean absolute error) performance and R correlation coefficient from training results of 0.0954; 0.2619 and 0.6538; test results 0.0392; 0.1606 and 0.7000 and validation results 0.0289; 0.1474 and 0.7889.* |

# SUPPLEMENTARY TABLES

Table S5. Results of phase I analysis of the ANN model 1 architecture (output results of oBrix predictions of lady finger banana).

| No | Hidden Layer (Units) | Code | Activation Function | | Training Performance | | | Testing Performance | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hidden Layer | Output Layer | MSE | MAE | R | MSE | MAE | R |
| 1 | 1 | Net1 | Logsig | Logsig | 0.3605 | 0.5811 | 0.2830 | 0.0818 | 0.1937 | 0.2893 |
| 2 | Net2 | Logsig | Tansig | 0.3967 | 0.6203 | 0.0310 | 0.4463 | 0.5870 | 0.1131 |
| 3 | Net3 | Logsig | Purelin | 0.3704 | 0.5982 | -0.5093 | 0.1930 | 0.4227 | -0.4445 |
| 4 | Net4 | Tansig | Logsig | 0.4756 | 0.6755 | -0.4816 | 0.2660 | 0.4689 | -0.5477 |
| 5 | Net5 | Tansig | Tansig | 1.2368 | 1.0136 | -0.3463 | 1.5013 | 1.0966 | -0.2098 |
| 6 | Net6 | Tansig | Purelin | 1.3828 | 1.1628 | -0.0253 | 2.7865 | 1.6487 | -0.1720 |
| 7 | Net7 | Purelin | Logsig | 0.0262 | 0.1323 | 0.5216 | 0.2130 | 0.4536 | 0.4402 |
| 8 | Net8 | Purelin | Tansig | 1.7096 | 1.2848 | -0.5519 | 2.0270 | 1.3983 | -0.3954 |
| 9 | Net9 | Purelin | Purelin | 0.0403 | 0.1667 | 0.2733 | 0.0466 | 0.1791 | 0.1132 |
| 10 | 3 | Net10 | Logsig | Logsig | 0.0485 | 0.1647 | 0.0546 | 0.0568 | 0.1775 | 0.3518 |
| 11 | Net11 | Logsig | Tansig | 0.0835 | 0.1892 | 0.4640 | 0.0699 | 0.1330 | 0.0609 |
| 12 | Net12 | Logsig | Purelin | 0.6881 | 0.8095 | -0.5241 | 0.1715 | 0.4093 | 0.1870 |
| 13 | Net13 | Tansig | Logsig | 0.2178 | 0.4041 | -0.0922 | 0.1625 | 0.3066 | 0.1178 |
| 14 | Net14 | Tansig | Tansig | 0.0375 | 0.1143 | -0.3582 | 0.0530 | 0.1979 | -0.0095 |
| 15 | Net15 | Tansig | Purelin | 6.9760 | 2.6173 | -0.6086 | 5.9257 | 2.3953 | -0.4461 |
| **16** | **Net16** | **Purelin** | **Logsig** | **0.0620** | **0.2027** | **0.5207** | **0.0336** | **0.1456** | **0.6468** |
| 17 | Net17 | Purelin | Tansig | 3.0423 | 1.7362 | -0.3302 | 3.0129 | 1.7277 | -0.1522 |
| 18 | Net18 | Purelin | Purelin | 3.0063 | 1.7019 | -0.3672 | 4.5699 | 2.0851 | -0.1784 |
| 19 | 9 | Net19 | Logsig | Logsig | 0.5109 | 0.6940 | 0.0099 | 0.2650 | 0.4606 | -0.2059 |
| 20 | Net20 | Logsig | Tansig | 0.2468 | 0.4746 | 0.2381 | 0.1260 | 0.2603 | 0.1485 |
| 21 | Net21 | Logsig | Purelin | 2.0123 | 1.4084 | 0.1061 | 0.5538 | 0.6137 | 0.3200 |
| 22 | Net22 | Tansig | Logsig | 0.5224 | 0.7097 | 0.0456 | 0.4606 | 0.6592 | 0.1664 |
| 23 | Net23 | Tansig | Tansig | 0.1450 | 0.3214 | -0.0328 | 0.0404 | 0.1328 | -0.1215 |
| 24 | Net24 | Tansig | Purelin | 1.6780 | 1.2374 | -0.0004 | 0.8757 | 0.7623 | 0.2609 |
| 25 | Net25 | Purelin | Logsig | 0.0514 | 0.1759 | 0.2599 | 0.0384 | 0.1547 | 0.0448 |
| 26 | Net26 | Purelin | Tansig | 2.8840 | 1.6906 | -0.1179 | 2.7886 | 1.6637 | 0.0598 |
| 27 | Net27 | Purelin | Purelin | 3.8613 | 1.9359 | 0.0501 | 3.1877 | 1.7528 | 0.2195 |
| 28 | 27 | Net28 | Logsig | Logsig | 0.4205 | 0.6325 | -0.0275 | 0.1150 | 0.2808 | -0.1526 |
| 29 | Net29 | Logsig | Tansig | 0.0585 | 0.1769 | -0.1845 | 0.1826 | 0.3314 | -0.2059 |
| 30 | Net30 | Logsig | Purelin | 0.6119 | 0.6754 | 0.3885 | 0.2846 | 0.4497 | 0.4915 |
| 31 | Net31 | Tansig | Logsig | 0.0880 | 0.2123 | 0.0409 | 0.0336 | 0.1325 | 0.0425 |
| 32 | Net32 | Tansig | Tansig | 1.5058 | 1.1005 | 0.1771 | 0.3870 | 0.4444 | 0.1227 |
| 33 | Net33 | Tansig | Purelin | 24.1103 | 4.7733 | -0.2112 | 21.6823 | 4.3755 | -0.2595 |
| 34 | Net34 | Purelin | Logsig | 0.0683 | 0.2523 | 0.5119 | 0.2525 | 0.4964 | 0.4243 |
| 35 | Net35 | Purelin | Tansig | 0.0623 | 0.2286 | 0.3959 | 0.5680 | 0.7337 | 0.3655 |
| 36 | Net36 | Purelin | Purelin | 9.5473 | 3.0438 | -0.4922 | 18.0245 | 4.1432 | -0.3248 |
| 37 | 81 | Net37 | Logsig | Logsig | 0.0753 | 0.2550 | 0.4179 | 0.2030 | 0.4259 | -0.2388 |
| 38 | Net38 | Logsig | Tansig | 2.5416 | 1.5812 | 0.1674 | 0.8466 | 0.6512 | 0.3805 |
| 39 | Net39 | Logsig | Purelin | 2.3357 | 1.3475 | -0.2226 | 2.1761 | 1.2224 | 0.2614 |
| 40 | Net40 | Tansig | Logsig | 0.4324 | 0.6420 | -0.3643 | 0.3841 | 0.5622 | -0.1853 |
| 41 | Net41 | Tansig | Tansig | 2.8662 | 1.6634 | -0.4874 | 2.9820 | 1.6612 | -0.1888 |
| 42 | Net42 | Tansig | Purelin | 41.8382 | 5.9204 | 0.5451 | 3.5486 | 1.4610 | 0.4544 |
| 43 | Net43 | Purelin | Logsig | 0.0379 | 0.1458 | 0.5488 | 0.0296 | 0.1293 | 0.2466 |
| 44 | Net44 | Purelin | Tansig | 0.7677 | 0.8302 | -0.3094 | 1.5282 | 1.1898 | -0.3487 |
| 45 | Net45 | Purelin | Purelin | 15.2012 | 3.6936 | 0.2229 | 23.8631 | 4.5312 | 0.0729 |

Note: bold print means the ANN architecture with the best performance results from the training and testing process. (MSE = Mean square error; MAE = Mean absolute error; R = Coefficient Correlation).

Table S6. Results of phase II analysis of the ANN model 1 architecture (output results of oBrix predictions for lady finger banana).

| No | Architectural Code | Learning Rate Value | Training Algorithm | Training Performance | | | Testing Performance | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MSE | MAE | R | MSE | MAE | R |
| 1 | NET 1 | 0.0001 | Traingdx | 0.0270 | 0.0818 | -0.4863 | 0.0179 | 0.0737 | -0.3219 |
| 2 | NET 2 | 0.001 | 0.0264 | 0.0965 | -0.1880 | 0.0647 | 0.2131 | -0.2957 |
| 3 | NET 3 | 0.01 | 0.0295 | 0.1052 | 0.0025 | 0.0312 | 0.1285 | -0.0445 |
| 4 | NET 4 | 0.1 | 0.0357 | 0.1312 | -0.2142 | 0.0384 | 0.1470 | -0.3487 |
| 5 | NET 5 | 1 | 0.0143 | 0.0698 | 0.5821 | 0.0306 | 0.1385 | 0.4865 |
| 6 | NET 6 | 0.0001 | Traingd | 0.4737 | 0.6765 | 0.3258 | 0.4982 | 0.6996 | 0.4130 |
| 7 | NET 7 | 0.001 | 0.4033 | 0.6244 | 0.3753 | 0.5565 | 0.7390 | 0.4115 |
| 8 | NET 8 | 0.01 | 0.1301 | 0.3113 | -0.4686 | 0.1018 | 0.2605 | -0.4780 |
| 9 | NET 9 | 0.1 | 0.4283 | 0.6432 | 0.2704 | 0.5970 | 0.7651 | 0.2843 |
| 10 | NET 10 | 1 | 0.0143 | 0.0698 | 0.5821 | 0.0303 | 0.1373 | 0.4854 |
| 11 | NET 11 | 0.0001 | Traingda | 0.0290 | 0.1110 | 0.5614 | 0.0108 | 0.0541 | 0.5784 |
| 12 | NET 12 | 0.001 | 0.1112 | 0.2789 | -0.3095 | 0.0372 | 0.1358 | -0.3403 |
| 13 | NET 13 | 0.01 | 0.4646 | 0.6708 | -0.4035 | 0.4428 | 0.6601 | -0.2613 |
| **14** | **NET 14** | **0.1** | **0.0620** | **0.2027** | **0.5207** | **0.0336** | **0.1456** | **0.6468** |
| 15 | NET 15 | 1 | 0.0143 | 0.0706 | 0.5815 | 0.0317 | 0.1421 | 0.4852 |
| 16 | NET 16 | 0.0001 | Traingdm | 0.0773 | 0.2525 | -0.2834 | 0.3458 | 0.5644 | -0.2025 |
| 17 | NET 17 | 0.001 | 0.3921 | 0.6133 | 0.1651 | 0.1223 | 0.3078 | 0.2608 |
| 18 | NET 18 | 0.01 | 0.0404 | 0.1328 | -0.2018 | 0.0346 | 0.1389 | -0.2284 |
| 19 | NET 19 | 0.1 | 0.4546 | 0.6632 | 0.0042 | 0.6657 | 0.8068 | -0.0018 |
| 20 | NET 20 | 1 | 0.0315 | 0.0994 | -0.4691 | 0.0296 | 0.1232 | -0.0757 |
| 21 | NET 21 | 0.0001 | Trainbfg | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 22 | NET 22 | 0.001 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 23 | NET 23 | 0.01 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 24 | NET 24 | 0.1 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 25 | NET 25 | 1 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 26 | NET 26 | 0.0001 | Trainrp | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 27 | NET 27 | 0.001 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1379 | 0.4859 |
| 28 | NET 28 | 0.01 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1381 | 0.4862 |
| 29 | NET 29 | 0.1 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4862 |
| 30 | NET 30 | 1 | 0.0143 | 0.0699 | 0.5822 | 0.0305 | 0.1381 | 0.4861 |
| 31 | NET 31 | 0.0001 | Trainlm | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 32 | NET 32 | 0.001 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 33 | NET 33 | 0.01 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 34 | NET 34 | 0.1 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |
| 35 | NET 35 | 1 | 0.0143 | 0.0698 | 0.5821 | 0.0305 | 0.1380 | 0.4861 |

Note: bold print means the ANN architecture with the best performance results from the training and testing process.

Table S7. Results of phase I analysis of the ANN model 2 architecture (output results of pH predictions of lady finger banana).

| No | Hidden Layer (Units) | Code | Activation Function | | Training Performance | | | Testing Performance | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hidden Layer | Output Layer | MSE | MAE | R | MSE | MAE | R |
| 1 | 1 | Net1 | Logsig | Logsig | 0.0257 | 0.1178 | 0.6511 | 0.0573 | 0.2112 | 0.7520 |
| 2 | Net2 | Logsig | Tansig | 0.0205 | 0.1116 | 0.7464 | 0.1703 | 0.3363 | 0.2545 |
| 3 | Net3 | Logsig | Purelin | 0.0301 | 0.1323 | 0.5693 | 0.0301 | 0.2521 | 0.4888 |
| 4 | Net4 | Tansig | Logsig | 0.0248 | 0.1151 | 0.6661 | 0.0570 | 0.2064 | 0.5238 |
| 5 | Net5 | Tansig | Tansig | 0.0267 | 0.1230 | 0.6329 | 0.0555 | 0.2079 | 0.7346 |
| 6 | Net6 | Tansig | Purelin | 0.0264 | 0.1212 | 0.6371 | 0.0662 | 0.2248 | 0.7076 |
| 7 | Net7 | Purelin | Logsig | 0.0154 | 0.0963 | 0.8118 | 0.1855 | 0.3564 | 0.2261 |
| 8 | Net8 | Purelin | Tansig | 0.0207 | 0.1122 | 0.7435 | 0.1695 | 0.3354 | 0.2574 |
| 9 | Net9 | Purelin | Purelin | 0.0317 | 0.1400 | 0.5362 | 0.0429 | 0.1809 | 0.6923 |
| 10 | 3 | Net10 | Logsig | Logsig | 0.0207 | 0.1092 | 0.7316 | 0.1277 | 0.3058 | 0.2266 |
| **11** | **Net11** | **Logsig** | **Tansig** | **0.0243** | **0.1150** | **0.6735** | **0.0440** | **0.1659** | **0.7199** |
| 12 | Net12 | Logsig | Purelin | 0.0273 | 0.1271 | 0.6227 | 0.0349 | 0.1588 | 0.6428 |
| 13 | Net13 | Tansig | Logsig | 0.0187 | 0.1012 | 0.7614 | 0.1171 | 0.2761 | 0.3537 |
| 14 | Net14 | Tansig | Tansig | 0.0233 | 0.1132 | 0.6916 | 0.1018 | 0.2348 | 0.0431 |
| 15 | Net15 | Tansig | Purelin | 0.0202 | 0.1058 | 0.7392 | 0.2902 | 0.4831 | 0.4910 |
| 16 | Net16 | Purelin | Logsig | 0.0182 | 0.1072 | 0.7778 | 0.1822 | 0.3522 | 0.2319 |
| 17 | Net17 | Purelin | Tansig | 0.0225 | 0.1166 | 0.7137 | 0.1596 | 0.3240 | 0.2869 |
| 18 | Net18 | Purelin | Purelin | 0.0317 | 0.1376 | 0.5367 | 0.0399 | 0.1740 | 0.7145 |
| 19 | 9 | Net19 | Logsig | Logsig | 0.0170 | 0.0928 | 0.7874 | 0.0133 | 0.2734 | 0.0356 |
| 20 | Net20 | Logsig | Tansig | 0.0230 | 0.1117 | 0.6954 | 0.6751 | 0.6975 | -0.4922 |
| 21 | Net21 | Logsig | Purelin | 0.0221 | 0.1114 | 0.7099 | 0.2985 | 0.3996 | 0.3193 |
| 22 | Net22 | Tansig | Logsig | 0.0124 | 0.0824 | 0.8496 | 0.1799 | 0.3486 | 0.1779 |
| 23 | Net23 | Tansig | Tansig | 0.0140 | 0.0878 | 0.8292 | 0.1596 | 0.3220 | 0.1739 |
| 24 | Net24 | Tansig | Purelin | 0.0145 | 0.0873 | 0.8235 | 1.2726 | 0.9293 | -0.0731 |
| 25 | Net25 | Purelin | Logsig | 0.0219 | 0.1182 | 0.7184 | 0.1745 | 0.3425 | 0.2520 |
| 26 | Net26 | Purelin | Tansig | 0.0203 | 0.1111 | 0.7502 | 0.1714 | 0.3374 | 0.2525 |
| 27 | Net27 | Purelin | Purelin | 0.0317 | 0.1376 | 0.5366 | 0.0413 | 0.1774 | 0.7098 |
| 28 | 27 | Net28 | Logsig | Logsig | 0.0114 | 0.0785 | 0.8648 | 0.1836 | 0.3540 | 0.1424 |
| 29 | Net29 | Logsig | Tansig | 0.0130 | 0.0811 | 0.8421 | 0.1803 | 0.3458 | 0.0027 |
| 30 | Net30 | Logsig | Purelin | 0.0150 | 0.0913 | 0.8162 | 0.7358 | 0.7294 | 0.3930 |
| 31 | Net31 | Tansig | Logsig | 0.0103 | 0.0735 | 0.8768 | 0.1694 | 0.3339 | 0.2173 |
| 32 | Net32 | Tansig | Tansig | 0.0133 | 0.0853 | 0.8402 | 0.1671 | 0.3141 | -0.0020 |
| 33 | Net33 | Tansig | Purelin | 0.0102 | 0.0757 | 0.8803 | 0.4791 | 0.4658 | -0.0012 |
| 34 | Net34 | Purelin | Logsig | 0.0203 | 0.1114 | 0.7464 | 0.1780 | 0.3462 | 0.2382 |
| 35 | Net35 | Purelin | Tansig | 0.0209 | 0.1128 | 0.7399 | 0.1685 | 0.3343 | 0.2602 |
| 36 | Net36 | Purelin | Purelin | 0.0317 | 0.1376 | 0.5367 | 0.0394 | 0.1730 | 0.7153 |
| 37 | 81 | Net37 | Logsig | Logsig | 0.0102 | 0.0734 | 0.8797 | 0.1620 | 0.3269 | 0.0126 |
| 38 | Net38 | Logsig | Tansig | 0.0142 | 0.0908 | 0.8279 | 0.0970 | 0.2205 | 0.3336 |
| 39 | Net39 | Logsig | Purelin | 0.0137 | 0.0878 | 0.8327 | 0.5277 | 0.5308 | 0.2302 |
| 40 | Net40 | Tansig | Logsig | 0.0083 | 0.0671 | 0.9019 | 0.3251 | 0.3251 | 0.0483 |
| 41 | Net41 | Tansig | Tansig | 0.0111 | 0.0783 | 0.8686 | 0.1197 | 0.2613 | 0.2602 |
| 42 | Net42 | Tansig | Purelin | 0.0103 | 0.0767 | 0.8765 | 1.5338 | 1.5338 | 0.3815 |
| 43 | Net43 | Purelin | Logsig | 0.0224 | 0.1183 | 0.7126 | 0.1723 | 0.3397 | 0.2574 |
| 44 | Net44 | Purelin | Tansig | 0.0240 | 0.0240 | 0.6881 | 0.1477 | 0.3094 | 0.3235 |
| 45 | Net45 | Purelin | Purelin | 0.0317 | 0.1376 | 0.5367 | 0.0387 | 0.1712 | 0.7175 |

Note: bold print means the ANN architecture with the best performance results from the training and testing process.

Table S8. Results of phase II analysis of the ANN model 2 architecture (output results of pH predictions for lady finger banana).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Architectural Code | Learning Rate Value | Training Algorithm | Training Performance | | | Testing Performance | | |
| MSE | MAE | R | MSE | MAE | R |
| 1 | NET 1 | 0.0001 | Traingdx | 0.0262 | 0.1199 | 0.6405 | 0.0507 | 0.1879 | 0.5846 |
| 2 | NET 2 | 0.001 | 0.0256 | 0.1192 | 0.6506 | 0.0408 | 0.1602 | 0.6035 |
| 3 | NET 3 | 0.01 | 0.0146 | 0.0913 | 0.8197 | 0.1818 | 0.3529 | 0.2430 |
| 4 | NET 4 | 0.1 | 0.0268 | 0.1244 | 0.6301 | 0.0711 | 0.2244 | 0.6343 |
| 5 | NET 5 | 1 | 0.0224 | 0.1124 | 0.7042 | 0.1055 | 0.2625 | 0.3898 |
| 6 | NET 6 | 0.0001 | Traingd | 0.2136 | 0.3618 | 0.5744 | 0.5322 | 0.5886 | 0.6157 |
| 7 | NET 7 | 0.001 | 0.0532 | 0.1947 | -0.1435 | 0.1337 | 0.2922 | -0.1517 |
| 8 | NET 8 | 0.01 | 0.0469 | 0.1674 | 0.1238 | 0.3478 | 0.4266 | -0.0660 |
| 9 | NET 9 | 0.1 | 0.0346 | 0.1447 | 0.4702 | 0.0701 | 0.2240 | 0.6092 |
| 10 | NET 10 | 1 | 0.0237 | 0.1174 | 0.6835 | 0.0625 | 0.1979 | 0.6167 |
| 11 | NET 11 | 0.0001 | Traingda | 0.1989 | 0.4015 | 0.6206 | 0.1713 | 0.3142 | 0.7343 |
| 12 | NET 12 | 0.001 | 0.7565 | 0.8483 | 0.4074 | 0.3687 | 0.5455 | 0.6878 |
| 13 | NET 13 | 0.01 | 0.3277 | 0.4791 | -0.4187 | 0.2782 | 0.4421 | -0.5112 |
| **14** | **NET 14** | **0.1** | **0.0243** | **0.1150** | **0.6735** | **0.0440** | **0.1659** | **0.7199** |
| 15 | NET 15 | 1 | 0.0290 | 0.1294 | 0.5907 | 0.0638 | 0.2229 | 0.6821 |
| 16 | NET 16 | 0.0001 | Traingdm | 1.9361 | 1.3708 | -0.2336 | 2.2003 | 1.4573 | -0.1308 |
| 17 | NET 17 | 0.001 | 0.0773 | 0.2205 | -0.1002 | 0.2610 | 0.3883 | -0.0224 |
| 18 | NET 18 | 0.01 | 0.1721 | 0.3750 | 0.1264 | 0.4076 | 0.5393 | -0.0398 |
| 19 | NET 19 | 0.1 | 0.6556 | 0.7747 | -0.3730 | 1.6741 | 1.2243 | -0.6259 |
| 20 | NET 20 | 1 | 0.3298 | 0.5294 | -0.3101 | 0.1802 | 0.3456 | -0.5988 |
| 21 | NET 21 | 0.0001 | Trainbfg | 0.0135 | 0.0862 | 0.8355 | 0.1905 | 0.3631 | 0.2052 |
| 22 | NET 22 | 0.001 | 0.0091 | 0.0729 | 0.8913 | 0.0785 | 0.2024 | 0.2191 |
| 23 | NET 23 | 0.01 | 0.0129 | 0.0826 | 0.8428 | 0.1906 | 0.3633 | 0.2093 |
| 24 | NET 24 | 0.1 | 0.0211 | 0.1070 | 0.7256 | 0.0303 | 0.1399 | 0.7045 |
| 25 | NET 25 | 1 | 0.0135 | 0.0862 | 0.8355 | 0.1905 | 0.3631 | 0.2052 |
| 26 | NET 26 | 0.0001 | Trainrp | 0.0157 | 0.0934 | 0.8057 | 0.1671 | 0.3298 | 0.2439 |
| 27 | NET 27 | 0.001 | 0.0158 | 0.0970 | 0.8035 | 0.1442 | 0.2917 | 0.1568 |
| 28 | NET 28 | 0.01 | 0.0135 | 0.0851 | 0.8351 | 0.1786 | 0.3492 | 0.2321 |
| 29 | NET 29 | 0.1 | 0.0168 | 0.0974 | 0.7890 | 0.1442 | 0.3070 | 0.3664 |
| 30 | NET 30 | 1 | 0.0187 | 0.1001 | 0.7608 | 0.0547 | 0.1651 | 0.5342 |
| 31 | NET 31 | 0.0001 | Trainlm | 0.0122 | 0.0831 | 0.8520 | 0.0826 | 0.2128 | 0.1625 |
| 32 | NET 32 | 0.001 | 0.0106 | 0.0761 | 0.8724 | 0.0602 | 0.2098 | 0.1525 |
| 33 | NET 33 | 0.01 | 0.0097 | 0.0744 | 0.8844 | 1.1330 | 0.8386 | -0.2838 |
| 34 | NET 34 | 0.1 | 0.0116 | 0.0813 | 0.8599 | 0.0790 | 0.2146 | 0.0518 |
| 35 | NET 35 | 1 | 0.0086 | 0.0704 | 0.8982 | 0.0814 | 0.2542 | 0.3760 |

Note: bold print means the ANN architecture with the best performance results from the training and testing process.

Table S9. Results of phase I analysis of the ANN model 3 architecture (output results of oBrix and pH predictions of lady finger banana).

| No | Hidden Layer (Units) | Code | Activation Function | | Training Performance | | | Testing Performance | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hidden Layer | Output Layer | MSE | MAE | R | MSE | MAE | R |
| 1 | 1 | Net1 | Logsig | Logsig | 0.1005 | 0.2627 | 0.4863 | 0.2242 | 0.3708 | 0.5000 |
| 2 | Net2 | Logsig | Tansig | 2.6091 | 1.6013 | 0.3724 | 2.7570 | 1.6463 | 0.3651 |
| 3 | Net3 | Logsig | Purelin | 1.7983 | 1.3133 | -0.3655 | 2.0173 | 1.3950 | -0.2328 |
| 4 | Net4 | Tansig | Logsig | 0.0982 | 0.2430 | 0.3664 | 0.1016 | 0.2370 | 0.2412 |
| 5 | Net5 | Tansig | Tansig | 1.1115 | 0.8290 | 0.5533 | 1.3277 | 0.9170 | 0.4740 |
| 6 | Net6 | Tansig | Purelin | 0.6204 | 0.7036 | 0.6095 | 0.6850 | 0.7672 | 0.2360 |
| 7 | Net7 | Purelin | Logsig | 0.2116 | 0.3814 | 0.5271 | 0.2355 | 0.3857 | 0.4793 |
| 8 | Net8 | Purelin | Tansig | 0.1815 | 0.3517 | 0.6376 | 0.7834 | 0.6931 | 0.5971 |
| 9 | Net9 | Purelin | Purelin | 0.8840 | 0.8277 | 0.4876 | 1.1181 | 0.8048 | 0.4908 |
| **10** | 3 | **Net10** | **Logsig** | **Logsig** | **0.0954** | **0.2619** | **0.6538** | **0.0392** | **0.1606** | **0.7000** |
| 11 | Net11 | Logsig | Tansig | 2.3933 | 1.5092 | -0.4504 | 2.5513 | 1.5837 | 0.4198 |
| 12 | Net12 | Logsig | Purelin | 0.6428 | 0.6164 | 0.4699 | 0.9792 | 0.7875 | 0.4388 |
| 13 | Net13 | Tansig | Logsig | 0.1753 | 0.3635 | 0.2670 | 0.1853 | 0.3721 | -0.2935 |
| 14 | Net14 | Tansig | Tansig | 1.2772 | 0.8840 | 0.5273 | 1.3531 | 0.8932 | 0.4773 |
| 15 | Net15 | Tansig | Purelin | 2.5044 | 1.4974 | 0.5419 | 2.3529 | 1.4178 | 0.3631 |
| 16 | Net16 | Purelin | Logsig | 0.3779 | 0.5353 | -0.4860 | 0.4049 | 0.5474 | -0.4427 |
| 17 | Net17 | Purelin | Tansig | 1.6046 | 1.1113 | -0.5744 | 1.3180 | 1.1004 | 0.1562 |
| 18 | Net18 | Purelin | Purelin | 2.5194 | 1.4844 | -0.6442 | 1.5129 | 1.1561 | -0.6583 |
| 19 | 9 | Net19 | Logsig | Logsig | 0.0617 | 0.1999 | 0.5991 | 0.1405 | 0.2827 | 0.4697 |
| 20 | Net20 | Logsig | Tansig | 1.7805 | 1.2584 | -0.3279 | 2.0565 | 1.4058 | 0.2658 |
| 21 | Net21 | Logsig | Purelin | 0.5947 | 0.7106 | 0.3219 | 0.2346 | 0.3674 | 0.4559 |
| 22 | Net22 | Tansig | Logsig | 0.4675 | 0.6305 | -0.4737 | 0.5336 | 0.6886 | -0.3550 |
| 23 | Net23 | Tansig | Tansig | 2.0647 | 1.3657 | -0.1892 | 1.4262 | 0.9843 | -0.2418 |
| 24 | Net24 | Tansig | Purelin | 3.7972 | 1.8907 | -0.2356 | 4.4784 | 1.8838 | 0.2531 |
| 25 | Net25 | Purelin | Logsig | 0.4366 | 0.6104 | -0.5289 | 0.4536 | 0.6050 | -0.4879 |
| 26 | Net26 | Purelin | Tansig | 1.1395 | 0.8343 | 0.5374 | 1.1164 | 0.7908 | 0.5024 |
| 27 | Net27 | Purelin | Purelin | 1.9407 | 1.3487 | 0.4438 | 1.8629 | 1.2768 | 0.4371 |
| 28 | 27 | Net28 | Logsig | Logsig | 0.1613 | 0.3321 | -0.4462 | 0.3471 | 0.5129 | -0.4806 |
| 29 | Net29 | Logsig | Tansig | 0.6165 | 0.6179 | 0.5346 | 1.1615 | 0.8090 | 0.5302 |
| 30 | Net30 | Logsig | Purelin | 5.2624 | 1.9858 | -0.4769 | 3.8357 | 1.6252 | -0.2426 |
| 31 | Net31 | Tansig | Logsig | 0.1260 | 0.2805 | 0.5116 | 0.0881 | 0.2343 | 0.2146 |
| 32 | Net32 | Tansig | Tansig | 0.0959 | 0.2306 | 0.2348 | 0.0993 | 0.2320 | -0.3399 |
| 33 | Net33 | Tansig | Purelin | 7.2885 | 2.3468 | 0.5037 | 1.8904 | 1.0817 | -0.3520 |
| 34 | Net34 | Purelin | Logsig | 0.4951 | 0.6714 | 0.4712 | 0.5661 | 0.7206 | 0.3948 |
| 35 | Net35 | Purelin | Tansig | 1.6434 | 0.9980 | -0.5372 | 1.7418 | 1.0661 | -0.4974 |
| 36 | Net36 | Purelin | Purelin | 3.6282 | 1.8217 | 0.5128 | 5.6364 | 2.3398 | 0.4799 |
| 37 | 81 | Net37 | Logsig | Logsig | 0.0748 | 0.2188 | 0.5205 | 0.1527 | 0.3337 | -0.4136 |
| 38 | Net38 | Logsig | Tansig | 1.6464 | 1.0396 | -0.5070 | 2.6228 | 1.5783 | 0.1390 |
| 39 | Net39 | Logsig | Purelin | 5.8945 | 2.0555 | -0.5375 | 7.4741 | 2.5340 | -0.4609 |
| 40 | Net40 | Tansig | Logsig | 0.1857 | 0.3454 | 0.5177 | 0.2053 | 0.3471 | 0.3706 |
| 41 | Net41 | Tansig | Tansig | 0.2725 | 0.3923 | 0.5302 | 0.6060 | 0.6051 | 0.6616 |
| 42 | Net42 | Tansig | Purelin | 33.1310 | 5.3792 | 0.4444 | 35.6074 | 5.1734 | -0.3486 |
| 43 | Net43 | Purelin | Logsig | 0.3963 | 0.5473 | -0.5537 | 0.4001 | 0.5368 | -0.4953 |
| 44 | Net44 | Purelin | Tansig | 0.1283 | 0.2824 | -0.2072 | 0.0905 | 0.2244 | 0.4821 |
| 45 | Net45 | Purelin | Purelin | 5.6223 | 2.1532 | 0.3713 | 7.8593 | 2.6695 | -0.0214 |

Note: bold print means the ANN architecture with the best performance results from the training and testing process.

Table S10. Results of phase II analysis of the ANN model 3 architecture (output results of oBrix and pH predictions for lady finger banana).

| No | Architectural Code | Learning Rate Value | Training Algorithm | Training Performance | | | Testing Performance | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MSE | MAE | R | MSE | MAE | R |
| 1 | NET 1 | 0.0001 | Traingdx | 0.3681 | 0.5591 | -0.5536 | 0.2937 | 0.4588 | -0.4594 |
| 2 | NET 2 | 0.001 | 0.1431 | 0.3077 | -0.1333 | 0.1245 | 0.2872 | -0.0491 |
| 3 | NET 3 | 0.01 | 0.0908 | 0.2336 | -0.0836 | 0.1077 | 0.2387 | -0.2016 |
| 4 | NET 4 | 0.1 | 0.0667 | 0.2165 | 0.5241 | 0.0881 | 0.2351 | 0.5493 |
| 5 | NET 5 | 1 | 0.0127 | 0.0767 | 0.8504 | 0.2333 | 0.3687 | 0.4833 |
| 6 | NET 6 | 0.0001 | Traingd | 0.1657 | 0.3518 | -0.5427 | 0.1017 | 0.2291 | -0.2659 |
| 7 | NET 7 | 0.001 | 0.1454 | 0.3184 | 0.1394 | 0.1171 | 0.2797 | 0.1185 |
| 8 | NET 8 | 0.01 | 0.2964 | 0.5064 | -0.5021 | 0.1773 | 0.3628 | -0.4951 |
| 9 | NET 9 | 0.1 | 0.1374 | 0.2915 | -0.1914 | 0.1101 | 0.2404 | -0.0868 |
| 10 | NET 10 | 1 | 0.0226 | 0.0981 | 0.7120 | 0.1331 | 0.2851 | 0.5862 |
| 11 | NET 11 | 0.0001 | Traingda | 0.3511 | 0.5175 | -0.4606 | 0.4937 | 0.6725 | 0.3481 |
| 12 | NET 12 | 0.001 | 0.0586 | 0.1782 | 0.2876 | 0.1033 | 0.2534 | 0.5370 |
| **13** | **NET 13** | **0.01** | **0.0954** | **0.2619** | **0.6538** | **0.0392** | **0.1606** | **0.7000** |
| 14 | NET 14 | 0.1 | 0.1983 | 0.3612 | 0.5302 | 0.1971 | 0.3556 | 0.4934 |
| 15 | NET 15 | 1 | 0.0189 | 0.0883 | 0.7675 | 0.2181 | 0.3437 | 0.5106 |
| 16 | NET 16 | 0.0001 | Traingdm | 0.2956 | 0.4597 | -0.6056 | 0.1780 | 0.3592 | -0.4675 |
| 17 | NET 17 | 0.001 | 0.3399 | 0.5196 | -0.5686 | 0.4305 | 0.5870 | -0.5044 |
| 18 | NET 18 | 0.01 | 0.3420 | 0.5459 | -0.5242 | 0.2249 | 0.3979 | -0.4608 |
| 19 | NET 19 | 0.1 | 0.1077 | 0.2719 | 0.4881 | 0.1226 | 0.2815 | 0.2490 |
| 20 | NET 20 | 1 | 0.0331 | 0.1241 | 0.5268 | 0.0460 | 0.1605 | 0.4627 |
| 21 | NET 21 | 0.0001 | Trainbfg | 0.0427 | 0.1564 | 0.7047 | 0.0709 | 0.2184 | 0.5745 |
| 22 | NET 22 | 0.001 | 0.0166 | 0.0821 | 0.7988 | 0.1382 | 0.2969 | 0.5019 |
| 23 | NET 23 | 0.01 | 0.0175 | 0.0808 | 0.7862 | 0.2220 | 0.3451 | 0.5056 |
| 24 | NET 24 | 0.1 | 0.0131 | 0.0807 | 0.8454 | 0.2210 | 0.4269 | 0.5075 |
| 25 | NET 25 | 1 | 0.0159 | 0.0851 | 0.8086 | 0.0702 | 0.2065 | 0.5483 |
| 26 | NET 26 | 0.0001 | Trainrp | 0.0107 | 0.0732 | 0.8753 | 0.0754 | 0.2240 | 0.4755 |
| 27 | NET 27 | 0.001 | 0.0102 | 0.0701 | 0.8812 | 0.2087 | 0.3660 | 0.3496 |
| 28 | NET 28 | 0.01 | 0.0113 | 0.0727 | 0.8687 | 0.1643 | 0.3034 | 0.2887 |
| 29 | NET 29 | 0.1 | 0.0091 | 0.0676 | 0.8950 | 0.1942 | 0.3507 | 0.3936 |
| 30 | NET 30 | 1 | 0.0102 | 0.0728 | 0.8816 | 0.2177 | 0.3713 | 0.4494 |
| 31 | NET 31 | 0.0001 | Trainlm | 0.0107 | 0.0676 | 0.8754 | 0.2114 | 0.3599 | 0.4691 |
| 32 | NET 32 | 0.001 | 0.0077 | 0.0616 | 0.9122 | 0.5280 | 0.6788 | -0.0809 |
| 33 | NET 33 | 0.01 | 0.0076 | 0.0624 | 0.9138 | 0.2391 | 0.3578 | 0.4822 |
| 34 | NET 34 | 0.1 | 0.0098 | 0.0660 | 0.8872 | 0.0641 | 0.1772 | 0.3738 |
| 35 | NET 35 | 1 | 0.0110 | 0.0735 | 0.8720 | 0.1236 | 0.2671 | 0.3857 |

## Note: bold print means the ANN architecture with the best performance results from the training and testing process