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Predicting solubility index of roller dried goat whole milk powder using Bayesian regularization ANN models

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ABSTRACT

A predictive model for predicting solubility index of roller dried goat whole milk powder using artificial neural network is proposed. The model takes into account solubility index of the product as a function of roller dried goat milk. Feedforward networks with one hidden layer were used with Bayesian regularization algorithm. The best fitting with the training data set was obtained with 4→5→1 topology, which made possible to predict solubility index of roller dried goat whole milk powder with accuracy, at least as good as the experimental error, over the whole experimental range. On the validation data set, simulations and experimental kinetics test were in good agreement. The developed model can be used for predicting solubility index of roller dried goat whole milk powder.

1. Introduction

Goat milk and its products, *viz.*, yoghurt, cheese and powder have three-fold significance in human nutrition: (1) feeding more starving and malnourished people in the developing world than from cow milk; (2) treating people afflicted with cow milk allergies and gastro-intestinal disorders, which is a significant segment in many populations of developed countries; and (3) filling the gastronomic needs of connoisseur consumers, which is a growing market share in many developed countries. Concerning (1), very much improvement in milk yield and lactation length of dairy goats, especially in developing countries must be accomplished through better education/extension, feeding and genetics. Concerning (2), little unbiased medical research to provide evidence

and promotional facts has been conducted, but is very much needed to reduce discrimination against goats and substantiate the many anecdotal experiences about the medical benefits from goat milk consumption, which abound in trade publications and the popular press. Goats have many unique differences in anatomy, physiology and product biochemistry from sheep and cattle, which support the contention of many unique qualities of dairy goat products for human nutrition. Concerning (3), a few countries like France have pioneered a very well-organized industry of goat milk production, processing, marketing, promotion and research, which has created a strong consumer clientele like in no other country, but deserves very much to be copied for the general benefit to human nutrition and goat milk producers. The physiological and biochemical facts of the unique qualities of goat milk are just barely known and little exploited, especially not the high levels in goat milk of short and medium chain fatty acids, which have recognized medical values for many disorders and diseases of people. The new concept of tailor making foods to better fit human needs has not been applied to goat milk and its products so far, otherwise the enrichment of short and medium chain fatty acids in goat butter, and their greater concentration compared to cow butter, could have become a valued consumer item. Also revisions to human dietary recommendations towards admitting the health benefits of some essential fats support the idea of promoting goat butter. While goat yoghurt, goat cheeses and goat milk powder are widely appreciated around the world (Haenlein, 2004).

According to Abraham (2006) artificial neural networks (ANN) have been developed as generalizations of mathematical models of biological nervous systems. A first wave of interest in neural networks emerged after the introduction of simplified neurons by McCulloch and Pitts also known as connectionist models. ANN is a network of collections of very simple processors "Neurons", each possibly having a small amount of local memory. The units operate only on their local data and on the inputs they receive via the connections or links which are unidirectional.

The term “feedforward” describes how neural network processes and recalls patterns. In a feedforward neural network, neurons are only connected forward. Each layer of the neural network contains connections to the next layer, but there are no connections back. “Backpropagation” type of neural network involves supervised training in which the network is provided with both sample inputs and anticipated outputs, which are compared with the actual outputs for given input. Using the anticipated outputs, the backpropagation training algorithm then takes a calculated error and adjusts the weights of the various layers backwards from the output layer to the input layer. The backpropagation and feedforward algorithms are often used together. It is permissible to create a neural network that uses the feedforward algorithm to determine its output and does not use the backpropagation training algorithm (Heatonsearch Website, 2011). According to Fraley and Raftery (2007) the Bayesian regularization allows the identification of a group with a single member while allowing the covariance matrix to vary between clusters, which is not possible without the prior.

ANNs in the field of foods have been applied recently. ANNs are dynamic new tools to analyze food quality, predict shelf life and model various attributes of foods. Some of the published work is presented as under.

1.1. Tomatoes

Movagharnejad and Nikzad (2007) investigated the experimental works on drying of tomatoes in a tray dryer covering different variables like power of heater and air flow velocity. The data were modeled using ANN and empirical mathematical equations, and the results were compared with experimental data, which showed that the predictions of the ANN model fit the experimental data more accurately in comparison to various mathematical equations.

1.2. Apple juice

Raharitsifa and Ratti (2010) studied the freeze-drying of foamed and non foamed apple juice, in order to assess if there was a reduction in process time due to foaming. Foams were prepared by whipping apple juice with methylcellulose or egg albumin at different concentrations. Foamed and non foamed juice samples having different thickness and different initial weight were frozen at – 40º C, and then freeze dried at 20º C during 48 h under vacuum. Sample weight loss and temperature were followed at different process times. A mathematical model based on ANN was developed to represent foam kinetics and temperature curves during freeze-drying. The observations revealed that freeze-drying of foamed materials is limited by heat transfer, while for non foamed ones, by mass transfer, and the insulation property characteristic of foams was more significant in slowing down the freeze-drying process than the increased surface area available for mass transfer due to foaming. From the

study it was concluded that the ANN can be used to obtain excellent predictions of moisture content and temperature during the freeze-drying process.

1.3. Butter

Gori *et al.* (2011) studied the seasonal variations of the fatty acids composition of butters over three seasons during a 12-month study in the protected designation of origin Parmigiano-Reggiano cheese area. Fatty acids were analyzed by GC-FID, and then computed by ANN. Compared with spring and winter, butter manufactured from summer milk creams showed an optimal saturated/un-saturated fatty acids ratio (−8.89 and −5.79%), lower levels of saturated fatty acids (−2.63 and −1.68%) and higher levels of mono-unsaturated (+5.50 and +3.45%), poly-unsaturated fatty acids (+0.65 and +0.17%), and rumenic acid (+0.55 and +3.41%), while vaccenic acid had lower levels in spring and higher in winter (−2.94 and +2.91%). ANN models were able to predict the season of production of milk creams, and classify butters obtained from spring and summer milk creams on the basis of the type of feeding regimens.

1.4. Milk

Sanzogni and Kerr (2001) forecasted the accuracy of milk production on dairy farms using a *ffann* (Feedforward ANN) with polynomial post-processing has been implemented. Historical milk production data was used to derive models that are able to predict milk production from farm inputs, using a standard *ffann*, a *ffann* with polynomial post-processing and multiple linear regression. Forecasts obtained from the models were then compared with each other. Within the scope of the available data, it was found that the standard *ffann* did not improve on the multiple regression technique, but the *ffann* with polynomial post processing did.

1.5. Meat

An ANN based predictive model for Leuconostoc mesenteroides growth in response to temperature, pH, sodium chloride and sodium nitrite developed by Garcia-Gimeno *et al.* (2005) was validated on vacuum packed, sliced, cooked meat products and applied to shelf-life determination (Zurera-Cosano et al., 2005). Lag-time (Lag), growth rate (Gr), and maximum population density (yEnd) of L. mesenteroides estimated by the ANN model were compared to those observed in vacuum-packed cooked ham, turkey breast meat, and chicken breast meat stored at 10.5°C, 13.5°C and 17.7°C, using bias and accuracy factors. The ANN model provided reliable estimates for the three kinetic parameters studied; with a bias factor of 1.09; 0.73 and 1.00 for Lag, Gr and yEnd, respectively and an accuracy factor of 1.26; 1.58 and 1.13 for Lag, Gr and yEnd, respectively. From the three kinetic parameters obtained by the ANN model, commercial shelf life were estimated for each temperature and compared with the tasting panel evaluation. The commercial shelf life estimated microbiologically*, i.e.,* times to reach 106.5 cfu/g was shorter than the period estimated using sensory methods.

ANNs have contributed in predicting several food products, *viz.*, honey (Benedetti *et al.,* 2004), fried potato chips (Marique *et al*., 2003), red pepper (Unluturk *et al.,* 2011), oil yield from groundnut kernels (Olajide *et al*., 2007), burfi (Goyal and Goyal, 2012a,2012b,2012c,2012d,2012e), coffee (Goyal and Goyal, 2012f); kalakand(Goyal and Goyal, 2012g, 2012h); milk cakes (2012i); cakes (Goyal and Goyal , 2011) and processed cheese (Goyal and Goyal, 2012j,2012k,2012l,2012m,2012n,2012o). The published literature suggests that ANN models are valuable tools in predictive modelling of food products. The main objective of this study is to develop single layer feedforward models using Bayesian regularization algorithm for predicting solubility index of roller dried goat whole milk powder.

2. Materials and methods

The input variables for developing soft computing models were the data of the product pertaining to loose bulk density, packed bulk density, wettability and dispersibility, while solubility index was the output variable (Fig. 1). Many different combinations of internal parameters, *i.e.*, data preprocessing, data partitioning approaches, number of hidden layers, number of neurons in each hidden layer, transfer function, error goal, *etc.* were tried in order to optimize the prediction performance. Different algorithms, *viz.,* Gradient Descent algorithm with adaptive learning rate, Bayesian regularization, Levenberg Marquardt algorithm and Powell Beale restarts conjugate gradient algorithm were explored. Bayesian regularization algorithm gave better results than other algorithms;

hence it was selected for conducting further experiments. The network was trained with 100 epochs, and neurons in each hidden layers varied from 5 to 50. MALTAB software was used for performing the experiments.

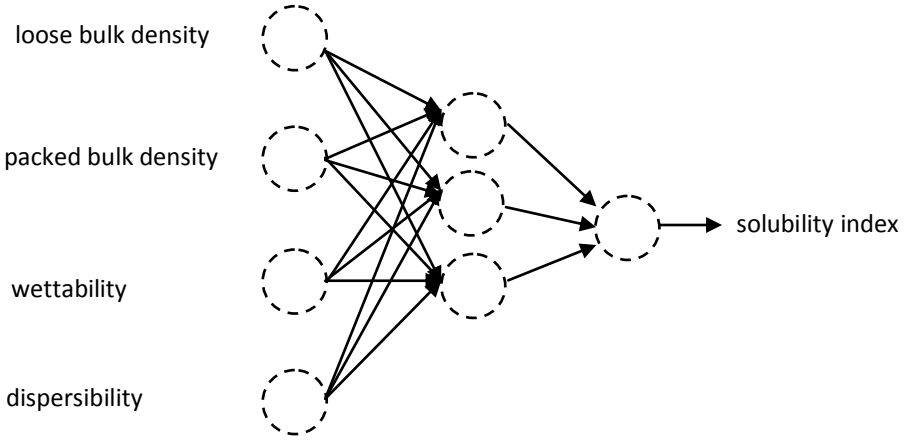

Fig. 1. Input and output variables of ANN model.

$$MSE = \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{n} \right)^2 \right] \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n} \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}} \right)^2 \right]} \quad (2)$$

$$R^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{{Q_{\exp}}^2} \right)^2 \right] \quad (3)$$

$$E^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp} - \overline{Q_{\exp}}} \right)^2 \right] \quad (4)$$

Where, $Q_{\exp}$ = Observed value; Q_{cal} = Predicted value; $\overline{Q}_{\exp}$ =Mean predicted value; n = Number of observations in dataset. Mean Square Error, MSE (1); Root Mean Square Error, RMSE (2); Coefficient of Determination, R^2 (3); and Nash - Sutcliffo Coefficient, E^2 (4) were used in order to compare the prediction ability of the developed models. Training pattern of ANN models is illustrated in Fig. 2.

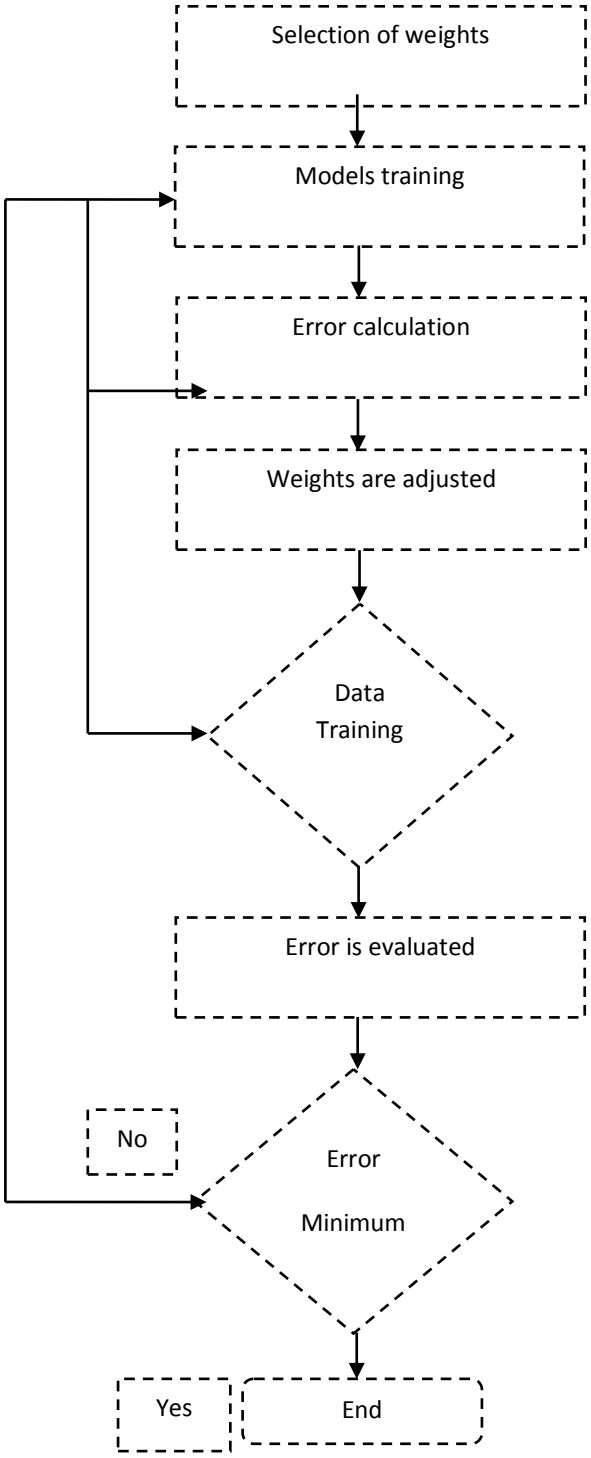

Fig. 2. Training pattern of ANN models.

3. Results and discussion

Performance matrices for predicting solubility index of dried goat whole milk powder are presented in Table1.

Table 1
Results of feedforward single hidden layer model using bayesian regularization algorithm.

Neurons	MSE	RMSE	R^2	E^2
5	*0.000382108*	*0.019547574*	*0.980452426*	*0.999617892*
8	0.004435773	0.066601602	0.933398398	0.995564227
10	0.001295971	0.035999592	0.964000408	0.998704029
15	0.00326073	0.057102801	0.942897199	0.99673927
20	0.003581401	0.059844804	0.940155196	0.996418599
25	0.003776771	0.061455436	0.938544564	0.996223229
30	0.00383688	0.061942554	0.938057446	0.99616312
35	0.004141511	0.064354574	0.935645426	0.995858489
40	0.003946668	0.062822509	0.937177491	0.996053332
45	0.003971385	0.063018928	0.936981072	0.996028615
50	0.004035014	0.063521759	0.936478241	0.995964986

Sutrisno *et al.* (2009) developed ANN models with back propagation algorithm to predict mangosteen quality during storage at the most appropriate pre-storage conditions which performed the longest storage period. In their experimental R^2 was found close to 1 (more than 0.99) for each parameter, indicating that the model was good to memorize data. Chegini *et al.* (2008) predicted process and product parameters in orange juice spray dryer using ANN modelling. They concluded that the ANN technology had been a useful tool to investigate, approximate and predict the physical properties of orange juice powder as well as process parameters of spray dryers. Their ANN model was able to predict the seven output parameters with RMSE lower than 0.042, R^2 higher than 0.93. Our ANN models indicated similar trend. Combination of 4→5→1(MSE: 0.000382108; RMSE: 0.019547574; R^2: 0.980452426; E^2: 0.999617892) gave the best fit (Table 1). These results show that ANN could potentially be used to estimate solubility index of roller dried goat whole milk powder.

4. Conclusion

The study led to believe that ANN modeling can be used to obtain good quality simulation of the solubility index of roller dried goat whole milk powder over a wide experimental range. This ANN modeling was validated with experimental data. The technological interest of this kind of modeling must be related to the fact that it is elaborated without any preliminary assumptions on the underlying mechanisms. The developed ANN procedure is simple and fast, and can alternatively be used for predicting the solubility index of the studied product.

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