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Computerized Model for Estimating Shelf Life of Roasted Coffee Sterilized Milk Drink

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Abstract – Today flavoured milks have become very popular as they contain nutrients compared to soft drinks. Coffee is the second most important product in the international market in terms of volume trade and the most important in terms of value. Multiple linear regression (MLR) model was developed to predict the shelf life of roasted coffee sterilized milk drink. Colour and appearance, flavour, viscosity and sediment were taken as independent variables, and overall acceptability as dependent variable. MSE, RMSE, R^2 and E^2 were used in order to compare the prediction potential of the developed model. The MLR model was found to be effective for estimating the shelf life of roasted coffee sterilized milk drink, as it showed high correlation between the actual and the predicted values.

Keywords – multiple linear regression; shelf life prediction; roasted coffee drink

1. Introduction

Flavoured milks have become very popular as they contain beneficial nutrients compared to soft drinks. The heat sterilization involves exposing food to a temperature generally exceeding 100°C for a period sufficient to inhibit enzymes and all forms of microorganisms, including bacteria spore. Sterilized milk is the product made by heating milk to high temperature (121^{o}C) with 15 m holding time so that it remains fit for human consumption for long period of time at room temperature. This technique has the advantage of preserving the organoleptic and nutritional quality of the product sterilized. The word "coffee" entered English in 1598 via Dutch koffie. This word was created via Turkish kahve, the Turkish pronunciation Arabic qahwa, a truncation of qahhwat al-bun or wine of the bean. One possible origin of the name is the Kingdom of Kaffa in Ethiopia, where the coffee plant originated; its name there is bunn or bunna [1].

The process of coffee roasting has been reported [2]. First the beans are roasted to just the right level to highlight any outstanding characteristics of the coffee, then the coffee is ground relative to how it will be brewed. Lastly the freshly roasted and freshly ground coffee is brewed at the right temperature for the correct amount of time. The first stage is endothermic. The green beans are slowly dried to become a yellow color and the beans begin to smell like toast or popcorn. The second step, often called the first crack, occurs at approximately 205°C in which the bean doubles in size, becomes a light brown color, and experiences a weight loss of approximately 5%. In the next step the temperature rises from 205°C to approximately 220°C, the color changes from light brown to medium brown, and a weight loss of approximately 13% occurs. The resulting chemical process is called pyrolysis and is characterized by a change in the chemical composition of the bean as well as release of carbon dioxide. The second step is followed by a short endothermic period which is followed by another exothermic step called the second crack. This second pyrolysis occurs between 225-230°C, and the roast color is defined as medium-dark brown. The second pop is much quicker sounding and the beans take on an oily sheen. Coffee roaster potential is maximized in roasting in order to maximize the sweetness and aroma of the coffee, while the bitterness and acidity are minimized. Most people focus on the latter and therefore roast extremely dark, yet without sweetness and aroma the espresso will never be palatable. This explains the unpopularity of straight espresso and the popularity of espresso based drinks where either milk or other flavors are used to replace the sweetness that was lost by roasting darkly. From 170-200°C the sugars in coffee begin to caramelize. From tasting pure sugar versus its caramelized component it is evident that uncaramelized sugar is much sweeter. The dark color of coffee is directly related to the caramelization of the sucrose in coffee. Therefore, to maximize sweetness it is necessary to minimize the caramelization of sucrose. Roast is stopped between the end of the first crack and less than half way through the second crack. Roasting chamber temperature between 205-215°C has been recommended.

2. Review Survey

Computerized models have successfully predicted the shelf lives of cakes [3, 4, 5, and 6], Kalakand [7], coffee drink [8, 9, and 10], milky white dessert [11], post-harvest coffee sterilized milk drink [12] and other products [14-16].

Artificial neural engineering and regression models were developed for predicting the shelf life of instant coffee drink. The experimental data of the product relating to colour and appearance, flavour, viscosity and sediment were used as input variables, while overall acceptability was used as output variable. The dataset consisted of 50 observations, which was divided into two disjoint subsets, *viz.*, training set having 40 observations (80% of total observations) and test set 10 observations (20% of total observations). The network was trained with 500 epochs. Neural network toolbox under MATLAB software was used for training the networks. From the investigation it was concluded that the multiple linear regression model was superior over radial basis model for forecasting the shelf life of instant coffee drink [8].

Goyal and Goyal applied computerized Elman and Radial basis models for estimating the shelf life of coffee sterilized milk drink. Colour and appearance, flavour, viscosity and sediment were taken as input variables. The overall acceptability was used as output variable. The dataset was randomly divided into two disjoint subsets, *viz.*, training set consisting of 40 observations (80% of total observations) and testing set comprising of 10 observations (20% of total observations). Number of neurons in each hidden layer varied from 1 to 30. The network was trained with 500 epochs. MSE, RMSE, R^2 and E^2 were used in order to compare the prediction performance of the developed computerized models. The Elman model with single hidden layer having eighteen neurons gave the best fit (MSE: 9.97756E-07, RMSE: 0.000998877, $R^{2:}$ 0.999990022, $E^{2:}$ 0.999996211), followed by Elman model with two hidden layers having seven neurons in the first layer and 5 neurons in the second layer (MSE: 8.48661E-06 , RMSE : 0.002913179, R^2 : 0.999915134, E^2 : 0.999999923); and Radial Basis model with spread constant as 100 (MSE : 4.1554E-05 , RMSE: 0.006446238, R^2:0.99958446, E^2 : 0.999951677). The investigation revealed that the artificial intelligence models are quite effective in predicting the shelf life of roasted coffee sterilized milk drink [12].

Till now no research has been reported for estimating the shelf life of roasted coffee sterilized cow milk drink, based on Multiple Linear Regression (MLR), hence this study was planned. The findings of this research would be very useful for the manufacturers of roasted coffee sterilized drink, consumers, regulatory authorities, researchers and academicians.

3. Materials and Methods

The experimental data relating to colour and appearance, flavour, viscosity and sediment were used as independent variables, and overall acceptability score as dependent variable for developing the MLR model for predicting the shelf life of roasted coffee sterilized cow milk drink stored at 30^{o} C.

3.1 Performance measures

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

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

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

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

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 applied in order to compare the prediction ability of the developed models.

4. Results and Discussion

4.1 Development of MLR Model

Regression reveals average relationship between two variables and makes possible to predict the yield. In mathematics *Y* is called a function of *X*, but in statistics it is termed as regression which describes relationship. Hence, regression is the study of functional relationship between two variables of which one is dependent *(Y)* and other is independent *(X)*. Regression analysis provides an estimate of values of the dependent variable from values of the independent variable. This estimation procedure is called the regression line. Regression analysis gives a measure of the error. With the help of regression coefficients the value of correlation coefficient can be determined. The multiple regression analysis gives the best linear prediction equation involving several independent variables. It also helps in finding the subset that gives the best prediction values of *Y*. The multiple regression equation describes the average relationship between dependent and independent variables which is used to predict the dependent variable. If *Y* depends partly on *X1* and partly on *X2* then the population regression equation is written as,

$$Y_R = \alpha - \beta_1 X_1 + \beta_2 X_2, \quad (5)$$

β_1 measures the average change in *Y* when X_1 increases by 1 unit, X_2 remaining unchanged it is called the partial

regression coefficient of Y on X_1 and β_2 the partial regression coefficient of Y on X_2 which measures the average change in Y when X_2 increases by 1 unit, X_1 remaining unchanged. Thus the regression model is

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon, \qquad (6)$$

where, $\varepsilon = N(0, \sigma^2)$ [13].

MLR model was developed for shelf life prediction of roasted coffee sterilized cow milk drink by using experimentally obtained overall acceptability score as dependent variable; and colour and appearance, flavour, viscosity and sediment as independent variables for predicting the value of dependent variable, *i.e.*, overall acceptability score. The results of the developed MLR model are presented in Table 1. The comparison of Actual Overall Acceptability Score (AOAS) and Predicted Overall Acceptability Score (POAS) for MLR model is illustrated in Fig.1.

Table 1. MLR model result

MSE	RMSE	R^2	E^2
4.01072E-05	**0.006333024**	**0.999598928**	**0.999984221**

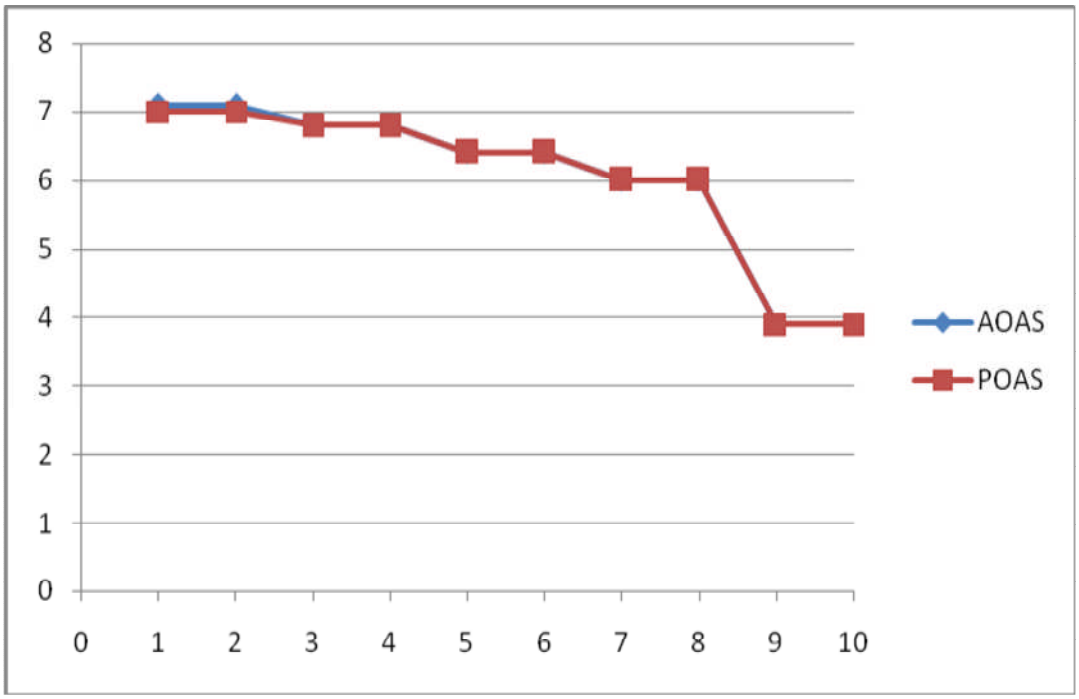

Fig. 1 Graphical representation of AOAS and POAS for MLR model

The observations show very high correlation between the actual and predicted values (Table 1). The results for R^2 (0.999598928) and E^2 (0.999984221) were excellent, revealing that the developed MLR model can successfully determine the shelf life of roasted coffee sterilized cow milk drink.

5. Conclusion

MLR model for estimating the shelf life of roasted coffee sterilized cow milk drink stored at 30°C was developed. For developing the model, colour and appearance, flavour, viscosity and sediment were used as independent variables; and overall acceptability score as the dependent variable. Mean square error, root mean square error, coefficient of determination and Nash-sutcliffo coefficient were used for comparing the prediction ability of the developed model. The results showed very good correlation between the independent variables and the dependent variable, suggesting that the developed model can successfully analyze and estimate the shelf life of roasted coffee sterilized cow milk drink.

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