Differentiation of ripe banana flour using mineral composition and logistic regression model

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Abstract: Cavendish (*Musa paradisiaca L, cv cavendshii*) and Dream (*Musa acuminata colla. AAA, cv 'Berangan'*) banana flours were prepared from ripe fruits collected from eleven markets located in Penang, Malaysia. The mineral composition (Na, K, Ca, Mg, Cu, Fe, Mn, Zn) of the flour were analyzed by atomic absorption spectrophotometer and the data obtained were analyzed using logistic regression model. Ripe banana flours were rich source of K and a fair source of other minerals, however logistic regression model identified Mg as an indicator to discriminate between the two types of banana flour affording 100 % correct assignation. Based on this result, mineral analysis may be suggested as a method to authenticate ripe banana flour. This study also presents the usefulness of logistic regression technique for analysis and interpretation of complex data.

Keyword: Mineral composition, logistic regression model, ripe banana flour

Introduction

It is scientifically accepted that the mineral composition of fruits is a distorted reflection of the trace mineral composition of the soil and environment in which the plants grow (Foster *et al*., 2002). Banana grown in similar environment or area of origin may be similar in mineral composition, and it may be possible to differentiate banana from different area of origin by using the mineral data composition (Hardisson *et al.,* 2001). However due to the differences in physiology, different varieties of banana should also exhibit differences in mineral composition. These differences may be used for authentication purposes and especially important when the banana fruits are no longer in their natural form. There is a substantial interest in the production and utilization of banana flour as new economical strategies. The preparation of banana flour from unripe banana has been reported (Rodriguez-Ambriz *et al.,* 2008). The advantages of unripe or green banana flour include the content of high resistant starch and dietary fiber that may confer beneficial benefits to human health (Faisant *et al*., 1995; Juarez *et al*., 2006). Similar to unripe banana flour, the introduction of ripe banana flour can offer new products with standardized nutrient composition for industrial and domestic uses. The advantages of banana flour prepared from ripe banana include high sugar content that is suitable for incorporation into food products requiring solubility, sweetness and high energy content. As more banana flour products are introduced into the market there will be a need to authenticate the varieties of banana used for the preparation of the flour. In Malaysia, two of the most important varieties are Cavendish (*Musa paradisiaca L, cv cavendshii*) and Dream (*Musa acuminata colla. AAA, cv 'Berangan'*) banana and their sales values for the year 2006 were 169.07 and 146.56 (RM/Kg) respectively (FAMA, 2007).

Logistic regression model is a statistical technique that is used to identify the most important variable or variables to discriminate between two cases and study the relationship between one or more explanatory variables (e.g. minerals) and dependent variable (e.g. two types of banana flour). It can also be used for prediction of response values (Erling, 1997; Agresti, 2002). Logistic regression model has been used in the field of food composition for analyzing complex data (Hernández, *et al*., 2005; Helena and Sarsfield, 2007). The objective of this study is to employ logistic regression model to differentiate between two types of banana flour based on mineral composition data.

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Materials and methods

Preparation of the sample

Two of the most common banana varieties, namely Cavendish (*Musa paradisiaca L, cv cavendshii*) and Dream (*Musa acuminata colla. AAA, cv 'Berangan'*) banana, were purchased from eleven markets around Penang, Malaysia. A total of 70-80 ripe banana of each variety were obtained from each market (A total of 1648 bananas for all samples). The fruits were peeled and cut into transverse slices of about 2 mm thickness. To reduce enzymic browning, slices were then dipped in 0.5% (w/v) sodium metabisulphite solution for 5 min, drained and dried in oven (AFOS Mini Kiln, at 60°C overnight). The dried samples were ground in a Retsch Mill Laboratory (Retsch AS200) to pass through 60 mesh screen to obtain banana flour. The flour was stored in airtight plastic packs in cold storage (15±2°C) for further analyses.

Proximate composition

Proximate analysis of banana flour was performed in triplicate following AOAC (1995) procedures and included the following : moisture by vacuum oven (method 934.06), protein by Kjeldahl nitrogen (method 920.152), and ash by direct analysis (method 940.26). The percentage of crude protein was estimated by multiplying the total nitrogen content by a factor of 6.25 (AOAC 1995). The lipid content was determined according to Bligh and Dyer (1959). Total carbohydrates were calculated by subtracting the total percent values of other measurements from 100. Proximate analyses were expressed as grams per 100 g of flour.

Analysis of minerals

For digestion, Millestone Ethos 900 microwave closed system was used. The flour samples were accurately weighed at 1.00 g and were transferred to 100 ml teflon vessels. Samples were digested with 6 ml of HNO_3 (65%), 1 ml of H_2O_2 (30%) in the microwave digestion system for 31 min (digestion conditions for microwave were: 2 min at 250 W, 2 min at 0 W, 6 min at 250 W, 5 min at 400 W, 8 min at 550 W and vent for 8 min). The digest for Ca and Mg were added with 0.5% (w/v) Lanthanum solution, otherwise for Na (+ 1 mg K^+/ml) and K (+ 1 mg N^+/ml) respectively, and final diluted to 100 ml with De-ionised water (18.2 MΩ cm). Blank digestion was carried out in the same way. For the elemental analysis, a Perkin-Elmer Analyst 3110 atomic absorption spectrometer with hollow cathode lamps was used in this study. All measurements were carried out in an air/acetylene flame.

Statistical methods

Logistic regression model

Logistic regression model or logit deals with the binary case, where the response variable consists of just two categorical values. Logistic regression model is mainly used to identify the relationship between one or more explanatory variables X_i and the dependent variable Y. Logistic regression model has been used for prediction and determining the most influential explanatory variables on the dependent variable (Cox and Snell, 1994).

The logistic regression model for the dependence of p_i (response probability) on the values of k explanatory variables $x_1, x_2, ..., x_k$ is given in below (Collett, 2003):

$$\log i\,(P_i) = \log\ (\frac{p_i}{1-p_i}) = b_0 + b_1 x_{1i} + ... + b_k x_k \quad (1)$$

$$\text{Or } p_i = \exp\ (\frac{b_0 + b_1 x_{1i} + ... + b_k}{1 + \exp\ (b_0 + b_1 x_{1i} + ... + b_k x_k}) \quad (2)$$

which is linear and similar to the expression for multiple linear regression.

where, $(\frac{p}{1-p})$ is the ratio of the probability of a success to the probability of a failure, and called odds,

b_0, b_i are parameters to be estimated, and p_i is the response probability.

In logistic regression model the predicted values for the response will never be ≤ 0 or ≥ 1, regardless of the values of the explanatory variables.

Results and discussion

Both type of flour had low moisture content (Table 1) similar to those determined in unripe banana flours (Juarez-Garcia *et al.*, 2006; Suntharalingham and Ravindran, 1993). The ash contents of the ripe banana flour were 4.44 and 4.65% for Cavendish and Dream banana flour respectively. These compare favorably with that of unripe banana flour from Cavendish variety (4.7%, Juarez-Garcia *et al.*, 2006) and 'Monthan' variety (4.2%, Suntharalingham and Ravindran, 1993) but were slightly higher than 'Alukehel' variety (3.3%, Suntharalingham and Ravindran, 1993). The protein and fat contents of the ripe banana flour were low, i.e. 4.78 and 4.11, 0.42

Table 1. Chemical composition[a] of banana flour prepared from ripe fruit (g/100 g)

Parameter	Type of banana	
	Cavendish	Dream
Moisture	9.57 ± 1.77	8.17 ± 0.18
Fat	0.42 ± 0.08	0.30 ± 0.01
Protein	4.78 ± 0.17	4.11 ± 0.71
Ash	4.44 ± 0.25	4.65 ± 0.22
Carbohydrate	80.80 ± 1.92	82.78 ± 0.76

[a]Values are means of three replicates ± standard deviation.

Table 2. Descriptive statistics (mean values[a] and standard deviation) of minerals for Cavendish and Dream banana flour (mg/100 g)

Parameter	Type of banana flour	
	Cavendish	Dream
Na	76.64 ± 30.0	3.11 ± 0.6
K	679.71 ± 81.2	699.56 ± 94.8
Ca	14.48 ± 1.5	11.66 ± 2.8
Mg	98.30 ± 5.2	75.42 ± 5.5
Cu	0.42 ± 0.0	0.36 ± 0.1
Fe	1.21 ± 0.2	1.04 ± 0.1
Mn	0.57 ± 0.0	0.62 ± 0.1
Zn	0.84 ± 0.1	0.76 ± 0.1

[a]Values are means of eleven independent samples collected from eleven different markets ± standard deviation.

and 0.30% for Cavendish and Dream banana flour respectively. The content of carbohydrate was high in both types of flour and this is expected since ripe banana is known to contain high level of sugar, starch and dietary fibers (Rodriguez-Ambriz *et al.*, 2008).

Since fruits are characterized by the content of certain mineral components (Juarez-Garcia *et al.*, 2006), similar characterization may also be performed for the fruit's flour. Descriptive statistics for the minerals in banana flour for the two varieties are presented as means ± standard deviation (Table 2). It can be seen that most of the minerals exhibited overlap between Cavendish and Dream banana flour after adding or subtracting the value of standard deviation, except for Na and Mg, but the fluctuation in Na content is very high in Cavendish banana flour, which indicates that the content of Na in banana flour is inconsistent from sample to sample for the same variety. Boxplot for mineral and trace elements in Cavendish and Dream banana flours are presented in Figs. 1 and 2 respectively, showing the maximum, minimum, median and the range of values of each parameter. These figures indicate clearly that K was the most abundant mineral in the flour, while other minerals were present in fair amount. This is expected since K is known to occur in abundance in fruits such as banana, and any vegetable products (Hardisson *et al.*, 2001).

Logistic regression was carried out to study the relationship between two types of banana flour (response) and eight minerals (explanatory variables). Stepwise method for variable selection was used to identify the most important explanatory variables (Na, K, Ca, Mg, Cu, Fe, Mn, Zn) that significantly influence the response (type of banana flour) and help in discriminating the two types of banana flour. Cu and Zn exhibited strong correlation with other variables. Thus, Cu and Zn were excluded from the analysis because of high correlation. Stepwise method identified only one parameter ($P < 0.001$) from minerals that is responsible in discriminating the two types of banana flour and yielded the following model (Eq.3):

$$p_i = \exp\frac{414.47 - 4.74\ Mg}{1 + \exp\ (414.47 - 4.74\ Mg)} \quad (3)$$

Table 3. The result of the classification using Logistic regression model

		Predicted location		%
		Cavendish	Dream	Correct assignation
Observed location	Cavendish	11	0	100
	Dream	0	11	100
Overall percentage				100

The main difference between Cavendish and Dream banana flour was mainly due to Mg content in banana flour, since only Mg exhibited significant effect to discriminate the two varieties of banana flour, while other parameters did not show significant effect and as a result of stepwise method were excluded from the model. This indicates that only Mg can help in differentiating between Cavendish and Dream banana flour. This model provided a good fit since the results of statistical test for goodness of fit (Cox and Snell R-square is 0.75 and Negelkerke R-square value is 1), showing that the logistic regression model was a good option in modeling the banana flour. The results of classification (Table 3) using logistic regression model in Eq.3 showed that 100 % of the banana flour obtained from different varieties was correctly classified to their respective variety. This is an agreement between model prediction and actual results. It can be said that the differences between Cavendish and Dream banana flour belong mainly to Mg content in the flour. Mg exhibited different content between Cavendish and Dream banana flour and consistent content in each variety (Fig. 3). Other minerals exhibited overlap between the flours which indicate that these minerals are not reliable to be an indicator to discriminate between different varieties of flour.

Conclusion

Based on the above results and discussion it can be concluded that logistic regression model identified only Mg out of eight minerals responsible in discriminating the two varieties of banana flour. Thus, Mg may be considered as an indicator to discriminate between the two types of banana flour. Mineral analysis may be used as an authenticating technique to differentiate between Cavendish and Dream banana flours.

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