Assessment of physical properties of ripe banana flour prepared from two varieties: Cavendish and Dream banana

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Abstract: Physical properties of ripe banana flour were studied in Cavendish and Dream banana, in order to distinguish the two varieties. Flour was analyzed for pH, total soluble solids (TSS), water holding capacity (WHC) and oil holding capacity (OHC) at 40, 60 and 80 °C, color values L*, a* and b*, back extrusion force and viscosity. Physical properties data were analyzed by cluster analysis (CA) and discriminant analysis (DA). CA showed that the two types of flour were different in terms of selected physical properties. DA indicated that WHC at 60 °C was the main contributor in discriminating the two types of flour.

Keyword: Physical properties, ripe banana flour, cluster analysis, discriminant analysis.

Introduction

Banana is one of the most consumed fruits in tropical and subtropical regions. New economical strategy to increase utilization of banana includes the production of banana flour when the fruit is unripe, and to incorporate the flour into various innovative products such as slowly digestible cookies (Aparicio-Saguilan *et al.*, 2007), high-fiber bread (Juarez-Garcia *et al.*, 2006) and edible films (Sothornvit and Pitak, 2007). The preparation of banana flour from unripe banana has been reported (Rodrı́guez-Ambriz *et al.,* 2008), and the flour has been shown to possess thickening and cooking properties nearly identical to those of isolated starch (Suntharalingam and Ravindran, 1993). In Malaysia and some other South East Asian countries however, banana is mainly consumed ripe. It will be interesting to prepare banana flour from ripe fruits. Ripe banana flour can potentially offer new products with standardized composition for various industrial and domestic uses. Banana flour prepared from ripe banana containing a quantity of sugar is suitable for incorporation into food products requiring solubility, sweetness and high energy content. Physical properties of fresh banana and banana constituents such as banana starch, have been studied and characterized (Zhang *et al.*, 2005), however the work to characterize physical properties of ripe banana flour with the intention of discriminating between flours prepared from different banana varieties has not been performed.

Commercial banana flour production is not yet common in Asia however this industry is gaining popularity in major banana producing countries in Africa (Emaga *et al.*, 2008). In its original form, it is relatively easy to differentiate between varieties (skin color, appearance, sizes and other dimensions). Once the pulp is processed into flour, identification of the banana origin and stage of ripeness becomes a challenge. For the purpose of quality control in the small and medium industries with limited budgets and manpower, it may be easier to perform physical measurements. The determination of chemical constituents of the flour such as sugar, starch and dietary fibers is more laborious and time consuming. Therefore it may be worthwhile to study the physical properties of banana flour prepared from ripe fruits of common varieties, and devise methods to discriminate banana flour based on its physical data. Statistical techniques that can be applied to perform this task is the multivariate statistical techniques (Markus *et al.,* 2002; Ricardo *et al.,* 2003).

Several varieties of banana can be found in the Malaysian market however two of the most important varieties are Cavendish (*Musa paradisiaca L, cv cavendshii*) and Dream (*Musa acuminata colla. AAA, cv 'Berangan'*) banana. Cavendish banana is more expensive than the Dream banana. Therefore the objective of this study was to characterize selected physical properties of ripe banana flour, and to use the data to discriminate between the two banana flours prepared from ripe Cavendish and Dream banana.

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Material and Methods

Preparation of ripe banana flour

Two banana varieties, namely Cavendish (*Musa paradisiaca L, cv cavendshii*) and Dream (*Musa acuminata colla. AAA, cv 'Berangan'*) banana, were purchased from eleven different markets around Penang Island, Malaysia. A total of 70-80 ripe banana (stage 5 of ripeness – more yellow than green) of each variety were obtained from each market (A total of 1648 bananas for all samples). The ripeness stage 5 was selected since this stage corresponds to various uses in industrial transformation and traditional culinary preparations (Emaga *et al,* 2008). The fruits were peeled and cut into transverse slices of about 2 mm thickness. 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 for 18 hrs. The dried samples were ground in a Retsch Mill Laboratory (Retsch AS200) to pass through 60 mesh screen to obtain banana flour. The yield of flour was calculated by dividing the amount of flour produced by the amount of fresh banana used, and the results were converted to g/Kg (g of flour/Kg of banana). The flour was stored in airtight plastic packs in cold storage (15±2°C) for further analyses.

pH, total soluble solid and viscosity

The pH of the flour was measured using a Inlab 421 Electrode attached with Delta 320 pH meter (Mettler-Toledo, Switzerland). Flour dispersion (8% (w/v)) was stirred for 5 min, allowed to stand for 30 min, filtered and the pH of filtrate measured (Suntharalingam and Ravindran, 1993). Total soluble solids (TSS) in the same flour slurries were measured using an Atago refractometer (Atago PAL-1, Co. Ltd., Tokyo, Japan) (Salvador and Fiszman, 2007).

Viscosity was determined as described by Fagbemi (1999). Flour was dispersed in water at 8% (w/v) concentration using a magnetic stirrer (1000 rpm) and heated from 30 to 95°C in a waterbath and kept at this temperature for 20 min. The slurry obtained was stirred constantly and cooled at room temperature. The viscosity was measured using a Brookfield Viscometer, model DV-E (Brookfield engineering laboratories, Inc, Middleboro, MA, USA) using spindle 3, at 50 rpm.

Water-holding capacity (WHC) and oil-holding capacity (OHC)

Twenty-five millilitres of distilled water or commercial olive oil were added to 1 g of dry sample, stirred and incubated at 40, 60 or 80°C for 1 h. Tubes were centrifuged at 3000 x *g* for 20 min, the supernatant was decanted, and the tubes were allowed to drain for 10 min at a 45° angle. The residue was weighed and WHC and OHC calculated as g water or oil per g dry sample, respectively (Rodrı´guez-Ambriz *et al.,* 2008).

Color

The instrumental measurement of banana flour color was carried out with a Colorimeter Minolta CM-3500d (Minolta, Spectrophotometer, USA) and the results were expressed in accordance with the CIELAB system with reference to illuminant D65 and a visual angle of 10°. The measurements were performed through a 6.4-mm-diameter diaphragm with an optical glass, placing the flour directly on the glass. The parameters determined were $L*$ ($L* = 0$ [black] and $L* = 100$ [white]), $a*$ ($-a*$ = greenness and $+a*$ = redness), $b*$ ($-b*$ = blueness and $+b*$ = yellowness).

Back extrusion force of slurry

A TA-XTplus Texture Analyzer (Stable Micro Systems, Godalming, UK) was used to evaluate the texture of the banana flour slurry (10% w/v). Back ward extrusion tests were conducted with the disc diameter 45 mm, setting the probe travel distance at 30 mm. Both tests were performed with a test speed of 5 mm/s, a trigger force of $5 \times g$, and force in compression mode. Force-time curves were recorded at a crosshead speed of 5 mm/s and recording speed was 5 mm/s to enable evaluation of back extrusion force (BEF) of the slurry. BEF of slurry may indicate gelation property potentials of the flour.

Multivariate statistical methods

Cluster analysis

Cluster analysis (CA) is a multivariate technique, whose primary purpose is to classify the objects of the system into categories or clusters based on their similarities, and the objective is to find an optimal grouping for which the observations or objects within each clusters are similar, but the clusters are dissimilar to each other. Hierarchical clustering is the most common approach in which clusters are formed sequentially. The most similar objects are first grouped, and these initial groups are merged according to their similarities. Eventually as the similarity decreases all subgroups are fused into a single cluster. CA was applied to physical properties of banana flour using a linkage method. In the linkage method, the distances or similarities between two clusters A and B is defined as the minimum distance between a point in A and a point in B:

$A, B) = \min\{d(y_i, y_j) \text{ for } y_i \text{ in A and } y_j \text{ in B}$

Where $d(y_i, y_j)$ is the Euclidean distance in (1).

At each step the distance is found for every pair of clusters and the two clusters with smallest distance (largest similarity) are merged. After two clusters are merged the procedure is repeated for the next step: the distances between all pairs of clusters are recalculated and the pair with minimum distance is merged into a single cluster. The result of a hierarchical clustering procedure can be displayed graphically using a tree diagram, also known as a dendrogram, which shows all the steps in the hierarchical procedure (Richard and Dean, 2002; Alvin, 2002).

Discriminant function

Discriminant analysis is a multivariate technique used for two purposes, the first purpose is description of group separation in which linear functions of the several variables (discriminant functions (DFs)) are used to describe or elucidate the differences between two or more groups and identifying the relative contribution of all variable to separation of the groups. Second aspect is prediction or allocation of observations to group in which linear or quadratic functions of the variable (classification functions (CFs)) are used to assign an observation to one of the groups (Richard and Dean, 2002; Alvin, 2002).

Results and discussion

General

The average length and diameter of Cavendish and Dream banana used for the study were 18.0 and 6.0, and 13.1 and 5.3 cm respectively. The average weight per fruit was 174 and 101 g for Cavendish and Dream banana, respectively. This indicates differences in the size of the two banana varieties. Ripe banana flours produced were pale or soft yellow in color, scattered with small black spots and presented banana flavor. After production of banana flour, the average yield of Cavendish and Dream banana flour were 183.4 and 274.3 g/Kg of banana fruit respectively. Chemical composition of both banana flours has been compared (AlKarkhi *et al.*, 2009). The protein and fat contents of the ripe banana flour were low, i.e. 4.78 and 4.11, 0.42 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 and dietary fibers (Rodriguez-Ambriz *et al.*, 2008).

Table 1 summarizes the mean and standard deviations of selected physical parameters for the two types of banana flour. The average TSS of Cavendish banana flour was slightly lower than that of Dream banana, thus indicating higher sugar content in the

Table 1. Mean and standard deviations (n =11) of selected physical parameters for the two types of banana flour

Parameter	Type of banana flour	
	Cavendish	Dream
pH	4.77 ± 0.16	4.63 ± 0.16
TSS (°Brix)	4.79 ± 0.34	5.03 ± 0.49
[a] WHC 40 °C	0.85 ± 0.09	0.52 ± 0.11
[a] WHC 60 °C	0.96 ± 0.09	0.65 ± 0.22
[a] WHC 80 °C	2.57 ± 0.71	2.68 ± 0.97
[b] OHC 40 °C	0.93 ± 0.06	0.84 ± 0.09
[b] OHC 60 °C	0.91 ± 0.08	0.86 ± 0.09
[b] OHC 80 °C	0.99 ± 0.15	1.05 ± 0.14
L^*	67.29 ± 2.30	66.18 ± 5.75
a^*	4.79 ± 0.90	6.68 ± 1.58
b^*	20.51 ± 1.88	26.03 ± 2.44
BEF (N)	0.87 ± 0.37	0.38 ± 0.12
Viscosity (mPa.s)	85.63 ± 2.66	62.30 ± 7.83

[a], water holding capacity; g water/g dry sample, [b], oil holding capacity; g oil/g dry sample

latter. In principle, this could cause less sweetness to be perceived in Cavendish banana flour which in turn could influence consumer acceptance. This suggestion however, needs further testing since the difference is marginal. TSS indicates soluble solid content of banana flour, and high TSS has been associated with high sucrose content in banana pulp (Bugaud *et al.*, 2006). It has been reported that the average starch content drops from 70 to 80% in the pre-climacteric period to less than 1% at the end of the climacteric period, while sugars, mainly sucrose, accumulate to more than 10% of the fresh weight of the fruit (Zhang *et al.*, 2005). As ripe banana was used for flour preparation the pH is expected to be mildly acidic with low acid content, but with a high sugar content.

Mean WHC increased with temperature, and ranged between 0.5 – 2.7 g/g dry sample. These values are lower than those reported in mango dietary fiber (12 and 15 g water/g dry sample) and mango peel dietary fiber (11 g/g) (Larrauri *et al.,* 1996), but were similar to those of fiber-rich unripe banana flour (2.5 g/g) (Rodrı´guez-Ambriz *et al.,* 2008). The average WHC40 and WHC60 were higher in the Cavendish banana flour as compared to that of Dream banana. WHC could be related to the physical state of starch (Waliszewski *et al.*, 2003), dietary fiber and protein in the flour. It was the release of amylose which has the capacity to effectively bind water molecules that

yielded a higher WHC (Rodrı´guez-Ambriz *et al.*, 2008). Starch however is not the principal component of ripe banana (Zhang *et al.*, 2005), leaving dietary fibers and protein as the main contributing factors that influence WHC of ripe banana flour. The highest WHC was attained at 80°C in all banana flour was also attributed to the effects of the solution properties of dietary fiber (Juarez-Garcia *et al.*, 2006) and to a less extent the gelatinization of starch in the flour that absorbs water into starch granules with concomitant swelling (Rodrı´guez-Ambriz *et al.*, 2008). Good water holding property implies the potentials of banana flour to be used as a thickener in liquid and semiliquid foods.

Another functional property of banana flour is oil holding capacity (OHC). Mean OHC ranged between 0.8 to 1.0 g oil/g dry samples at the three temperatures assessed. These values are slightly lower than that reported in fiber-rich banana powder that could hold 2.2 g oil/g dry sample (Rodrı´guez-Ambriz *et al.,* 2008), but are similar to that of mango dietary fiber with OHC in the range 1.0 – 1.5 g oil/g ((Larrauri *et al.,* 1996). Other products tested for OHC include mango peel dietary fiber (~ 4 g oil/g), (Larrauri *et al.,* 1996) and citrus peel fiber (2.35 – 5.09 g oil/g) (Chau and Huang, 2003). OHC relates to the hydrophilic character of starches present in the flour (Rodrı´guez-Ambriz *et al.,* 2008) that could be present in some quantity in Cavendish as well as in Dream banana
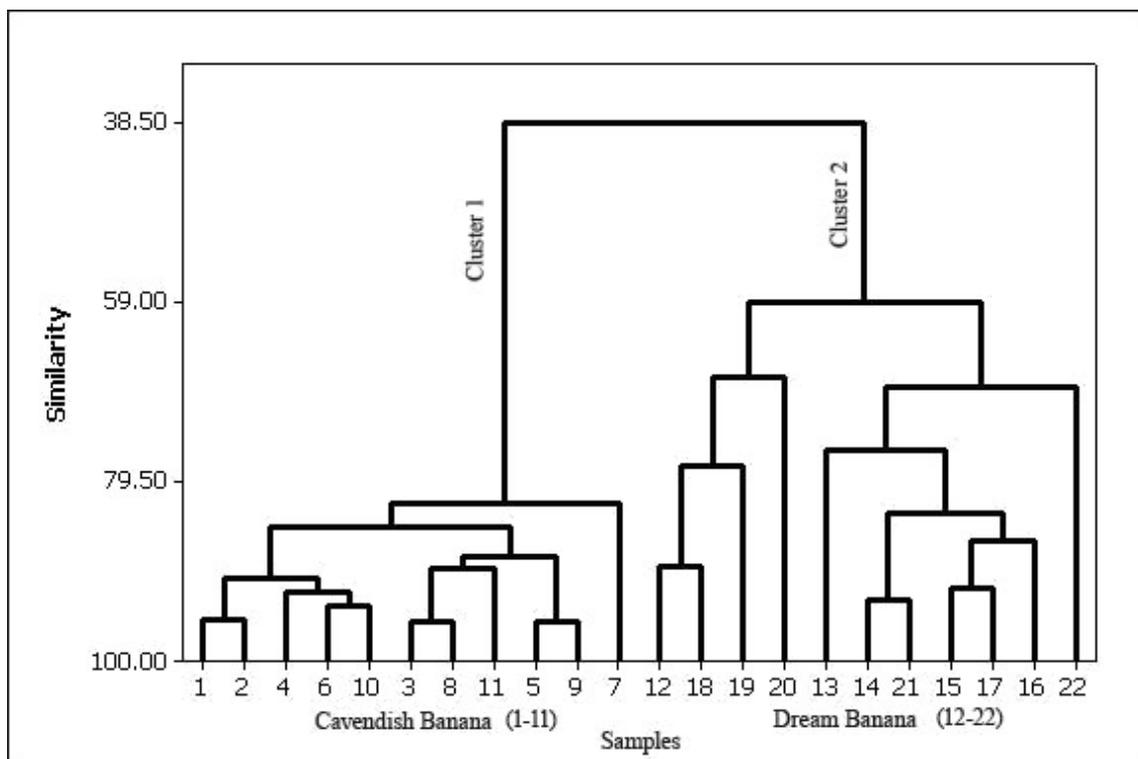

Figure 1. Dendrogram showing clustering of banana flour samples based on physical properties

flour. Good oil absorption capacities of the flours suggest that they may be useful in food preparations that involve oil mixing, such as in bakery products where oil is an important ingredient.

The mean L * values of the flour were similar (~ 67.0), indicating similarity in lightness color of the flour. Dream banana flour appeared to show more reddish and yellowness tones (higher a* and b* values) as compared to that of Cavendish flour. During ripening of banana, the flesh color changes from "opaque white' to "very soft yellow" thus reflecting different extents of starch hydrolysis and sugar synthesis (Salvador and Fiszman, 2007) in the banana varieties. As both flours were yellow in color with acceptably high b* values (yellowness tone), these ripe banana flours may be suitable for incorporation into products requiring high yellowness tones such as yellow noodle or certain bakery products. The average L* values of both flours however was similar. Even though some differences were noted in the color values of the flour, caution must be exercised when interpreting these data since scattered dark spots within the flour might have interfered with color analyses. In addition color changes of banana slices during drying might also complicate the interpretation of L*a*b* values. In view of color change during drying, more work should be performed to evaluate enzyme activity such as polyphenoloxidase (PPO), and total phenolic contents of banana slices in order to study color changes during drying of banana slices. This is because banana is known to undergo enzymic browning upon wounding (Vilas-Boas and Kader, 2006).

The average viscosity and BEF were 85.63 mPa.s and 0.87 N, and 62.30 and 0.38 N respectively for Cavendish and Dream banana flour. In all cases the average viscosity and BEF of Cavendish banana flour slurry were higher than those of Dream banana. The functionality of starch is largely related to its gelatinization and pasting characteristics. In theory, when banana flour is heated in water, starch granules swell at their gelatinization temperature. When amylose leaches out of the granules and swell, viscosity and textural changes result. Since starch content is low in ripe banana (Zhang *et al.*, 2005), the viscosity of ripe banana flour slurries could have been attributed to protein contents since protein content has been shown to increase with increasing ripeness of banana cultivars (Yomeni *et al.*, 2004). Other components with viscosity properties such as dietary fibers could also contribute to viscosity and BEF of banana flour. The differences in these physical properties may have certain implications in products incorporated with ripe banana flours.

Cluster analysis

Cluster analysis (CA) was used to identify the similarity groups between the banana flour samples. CA rendered a dendrogram as shown in Figure1, grouping all 22 samples into two statistically significant clusters. Cluster 1 (samples 1-11 for Cavendish banana flour) and clusters 2 (samples 12-22 for Dream banana flour) reveal that the two types of banana flour have different characteristics in terms of physical properties. Figure 1, also shows that Cavendish banana flour exhibited a consistent behavior more than Dream banana. This indicates that the values of physical properties of Dream banana flour show greater fluctuation. This grouping gives evidence that samples in each group share each other the sources of physical properties that were different from the other type of banana flour.

Table 2. Eigen-value of DF for the two types of banana flour

Function	Eigen-value	% of Variance	Cumulative %
1	35.35	100.00	100.00

Table 3. Wilks' Lambda for testing discriminant function validity

Test of Function	Wilks' Lambda	Chi-square	P-Value
1	0.03	48.51	0.00

Discriminant analysis

The DA applied on raw data consisted of thirteen parameters. Only one DF was found to discriminate the two varieties as shown in Table 2 . Wilk's Lambda test showed that DF is statistically significant as shown in Table 3. Furthermore 100% of the total variance between the two types of banana flour was explained by only one DF. The relative contribution for each parameter is given in equation 2.

(2)

$$Z = -0.65\ pH + 0.01\ TSS - 0.55\ WHC40$$
$$-1.34\ WHC60 + 0.25\ WHC80 + 0.50\ OHC40$$
$$+0.28\ OHC60 - 0.34\ OHC80 + 2.40\ L^* + 0.16\ a^*$$
$$+1.85\ b^* + 0.25\ BEF - 0.84\ Viscosity$$

L* and b* values and WHC60 exhibited strong contribution in discriminating the two types of flour and account for most of the expected variations in physical properties of the flour samples, while other parameters showed less contribution in explaining

Table 4. Classification results for discriminant analysis[a] of the two types of flour

Type of banana	% correct	Predicted group membership	
		Cavendish	Dream
Cavendish	100	11	0
Dream	100	0	11

[a] 100.0% of original grouped cases correctly classified.

the variation between the banana flour. The relative contribution of the parameters can be ranked as follows;

L* > b* > WHC60 > viscosity > pH > WHC40 > OHC40 > OHC80 > OHC60 > WHC80, BEF > a* > TSS.

Based on this ranking it may be concluded that L* and b* values and WHC60 are the most important physical properties that discriminate ripe Cavendish and Dream banana flour. However since color assessment was problematic due to the presence of dark spots and color changes occurred during drying of banana slices, it would be appropriate to dismiss color parameter as discriminating methods to differentiate the flour. TSS is the least reliable physical parameter to discriminate the flour since the contents of soluble solid in the flours were almost similar (Table 1).

The classification matrix (Table 4) showed that 100% of the cases were correctly classified to their respective groups. The results of classification also showed that significant differences existed between these two types of flour (Table 4), affording 100% correct assignation, which are expressed by in term of one discriminant function. This result is in agreement with CA which indicated that the two types of flour were different based on their physical properties.

Source identification

Relationship between the scores of discriminant function and the samples from various samples (Figure2) corresponded to the scores of discriminant function for various samples. The samples nos. 1-11 corresponded to banana samples of each variety. It could be seen from Figure2 that all Cavendish samples showed positive contribution to discriminant function, whereas Dream banana samples showed negative contribution. This difference was mainly due to

the L* and b* values and WHC60. The positive contribution was mainly attributed to positive coefficient of the parameters, while the negative contribution was mainly attributed to the negative coefficient of the parameters in equation 2.

Conclusion

The present study revealed some differences in physical properties of ripe Cavendish and Dream banana flour. Statistical analysis indicated that water holding capacity at 60°C were the main contributors in discriminating the two types of flours. Future work should involve comparison of physical properties of banana flour prepared from various stages of ripeness and varieties. This should be supported by chemical analysis of dietary fibers, starch and sugar composition in order to explain the differences in physical properties of the flour. Incorporation studies of ripe banana flour into strategic food products could also be attempted.

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