MATERIALS AND METHODS

Materials

1. Banana [Musa (ABB group) , ‘ Kluai Numwa ‘ variety maliong]
(starch content 28 % by Glucoamylase method AACC 1990 and total soluble solid 23-25° Brix)
2. STAR-DRI 100 Maltodextrin (dextrose equivalent 10-12, Abbra corporation Ltd.)

Chemical

The chemicals used for experiment were analytical grade (Merck Co., Ltd.)

1. Lithium chloride ($LiCl.H_2O$)
2. Potassium acetate ($KC_2H_3O_2$)
3. Magnesium chloride ($MgCl_2.6H_2O$)
4. Magnesium nitrate ($Mg (NO_3)_2 .6H_2O$)
5. Sodium nitrite ($NaNO_2$)
6. Sodium chloride (NaCl)
7. Calcium sulfate ($CaSO_4$)

Method

1. Determination of the Moisture Sorption Isotherm of Banana Powder.

1.1 Material

The unripen banana [*Musa* (ABB group) , ‘ Kluai Numwa ‘ variety maliong] was purchased from Amphur Bangkatum, Phitsanulok Province. All of them were kept at 30 ± 2°C until they were ripen and had total soluble solid value about 23-25° Brix.

1.2 Preparation of Banana Powder samples

Banana from 1.1 was peeled and used only the pulp at the outer portion then blanched at 80-85°C for 10 minutes. The pulp was blended into a puree. The puree was freeze-dried in a Freeze Dryer (LABCONCO Model 79340) at -40° C 55 mbar for 40 hours. The banana powder was prepared as shown in Figure 10. The freeze-dried materials were powdered and dehydrated to almost " zero" moisture by keeping them in desicators under vacuum and over $CaSO_4$ until a constant weight.

Banana

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Peeling and using (only the outer portion of pulp)

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Blanching (80-85° C 10 min.)

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Pulping

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Freeze drying at -40° C 55 mbar for 40 hours

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Grinding dried banana control temperature with liquid nitrogen

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Sieving through screen 100 mesh

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Banana powder

Figure 10 Process of banana powder production

1.3 Chemical analysis

Banana powder samples from 1.2) were analyzed for moisture, ashcontent, crude fiber, crude fat, protein, total carbohydrates and reducing sugar following the standard procedures of determination A.O.A.C (2000).

The moisture content of banana powder was determined by vacuum oven method two grams of sample were placed on a aluminum dish which as previously dried and weighed and the sample was dried in a vacuum oven (Binder VD 53) at 70±1°C for 6 h until the weight was constant. The crude protein content was calculated by converting the nitrogen content determined by Kjeldahl's method (6.25 X N) using Buchi (model B-435, B 323, B 412). Fat was determined using the Soxhlet system (Buchi model B-810). Ash content was determined by dry-ashing in a furnace oven (Fisher model 10-650-126) at 525°C for 24 h. Carbohydrates were calculated by subtracting the other components from the total. Fiber was determined using the Fiber tec system (Velp scientific model Fine). Reducing sugar was analyzed by Lane-Eynon Volumetric method. All determinations were performed in triplicate.

1.4 Determination of moisture sorption isotherms

The most common method used in the literature for measurement of water sorption isotherms is an isopiestic method. In this method, six sample of about five gram of banana powder samples were put on pre-weighed plastic cup placed into several air-sealed plastic vacuum desicators (diameter 15 cm.) containing different saturated salt solutions at 35°C while maintaining a equilibrium of relative humidity with 100 ml. saturated salt solutions. The standard salt solutions were prepared following the method described by Sablani, Rahman, and Labuza (2001) using: $LiCl.H_2O$, $KC_2H_3O_2$, $MgCl_2.6H_2O$, $Mg(NO_3)_2.6H_2O$, $NaNO_2$, and NaCl for a_w 0.113, 0.216, 0.321, 0.499, 0.628 and 0.749, respectively in the vacuum desicators. These desicators were placed in a temperature-controlled cabinet maintained at a constant temperature (35°C) as in Figure 11. Samples were weighed everyday until equilibrium had reached. Then, three of six samples were taken for equilibrium moisture measurement.

Moisture contents (g H_2O/100 g solids) were determined by vacuum oven (Binder VD 53) A.O.A.C.(2000) 934.06.

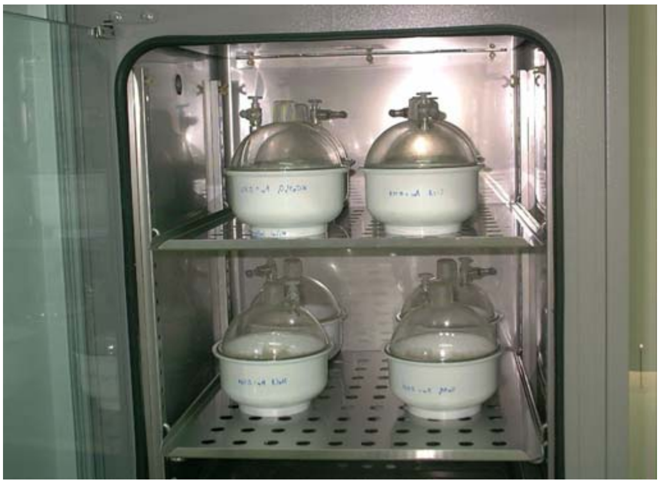

Figure 11 Determination of sorption isotherm using desicators placed in temperature-controlled cabinet.

Sorption Isotherm model

The adIsorption isotherm of banana powder was obtained by ploting the equilibrium moisture contents against water activity on graph paper. The Guggenheim-Anderson-son-deBor (GAB) (Eq. 3) was selected as representative model for the adsorption isotherm of banana powder by fitting the model with experimental data.

$$M = \frac{(M_o C k a_w)}{((1 - k a_w)(1 - k a_w + C k a_w))} \quad (3)$$

Where a_w is water activity; M is water content of sample on dry basis; M_0 is the monolayer water content; C is the Guggenheim constant; K is the constant correcting properties of multilayer molecules with respect to bulk liquid.

2. Determination of Glass Transition Temperature (T_g).

The other three equilibrated sample from 1.4 were used to determine glass transition temperature.The glass transition temperature was determined by differential scanning calorimetry using (DSC7, Perkin Elmer, Norwalk, Conn., U.S.A.) provided with a PC for simultaneous treatment of the data (7 Series/Window) and a system for temperature control using liquid nitrogen (Perkin Elmer Intra Cooler 2 control cooling accessory). The instrument was calibrated for temperature and heat flow with indium (T_g = 156.6°C and ΔH = 28.5 J/g, Perkin Elmer standard). A sample of approximately 8 to 12 mg was transferred into an aluminum pan, sealed and weighed immdiately. An empty similar aluminum pan was used as a reference. The pans was cooled to – 60°C. The scanning rate at 5°C/min from – 60°C to 100 °C. The glass transition temperature appeared as an endothermic shift in the specific heat capacity and discontinuity in the baseline. Thermograms were obtained for samples of different moisture content and they were analyzed for the onset, midpoint and the end of glass transition. The results were obtained in triplicate.

3. Mathematical Models and Correlation of Glass Transition Temperature and Water Activity/ Water Content of Banana Powder.

The following steps were used to correlate glass transition temperature and water activity data obtained from 2.

3.1 The GAB equation (Eq. 3) was used to predict water content of as function of water activity from 1.4.

3.2 The linear and the Gordon and Taylor equations (Eq. 5 and 6) were used to predict the T_g as function of water fraction.

Linear equation:

$$T_g = T_{gs} + \left(T_{gw} - T_{gs}\right)a_w \qquad (5)$$

Gordon and Taylor (1952) equation:

$$T_g = \frac{T_{gs}X_s + kT_{gw}X_w}{X_s + kX_w} \qquad (6)$$

Where T_g , T_{gs}, and T_{gw} are glass transition temperatures of the sample, solid matrix and water, respectively. X_s and X_w are the corresponding percentages of solid and water contents, and k is an empirical parameter. The equation parameters T_{gs} Eq. (5) and k Eq. (6) are estimated using non-linear regression analysis while considering that the glass transition temperature of pure water was taken as T_{gw} = -135°C.

3.3 These linear equation (Eq. 5) and GAB equation (Eq. 3) were combined to predict T_g and moisture content (M) as function of a_w.

4. Effect of Maltodextrin on the Quality of Banana Flake Product.

4.1 Development and prepartion of banana flake samples

The banana obtained from 1.1) were peeled and used only outer portion then blanched at 80-85°C for 10 minutes. The pulp was blended with maltodextrin (dextrose equivalent 10-12) at the concentration of 0, 0.9, 1.8, and 2.7% w/w. Then the moisture content of banana pulp was adjusted to 75 %. The samples were dried using drum dryer operating with speed 5 rpm at 150°C, and drum clearance 1 mm. The dried banana flake product was screened were separated into 5 mesh using sieving. The banana flake was prepared as shown in Figure 12.

4.2 Chemical analysis

Chemical analysis of banana flake samples obtained from 4.1) were performed as described in 1.3.

4.3 Physical properties determination of banana flake

4.3.1 Hardness

Hardness of banana flake samples obtained from 4.1 was measured by compression test using Lloyd TA 500 500 N set at a distance of 30 mm. Banana flake were pressed by 60 % in the middle cylinder (size of cylinder: diameter 30 mm.) high 40 mm. which banana flake were filled with a cylindrical ball 10 mm (diameter of 25mm) at a speed of 20 mm/min, trigger 0.005 N, sample was compress.

Each condition was done 20 replicated measure. Maximum force was collected as hardness of sample.

Banana

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Peeling and using only outer portion

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Blanching 80-85° C 10 min.

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Blending to be puree

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Mixture with maltodextrin

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Drying using Drum Drier 5 rpm at 150°C, and drum clearance 1 mm.

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Flake

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Sieving by screen 5 mesh

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Banana flake

Figure 12 Process of banana flake.

4.3.2 Color Analysis

Color of banana flake samples was evaluated with regard to'*L**'(lightness), '*a**'(redness and greenness), '*b**' (yellowness and blueness) using Minolta spectrophotometer CM-3500d. *L** is an approximate measurement of luminosity, which is the property according to which each color can be considered as equivalent to a member of the gray scale, between black and white, taking values within the range 0 to 100; *a** takes positives values for reddish colors and negative values for greenish ones, whereas *b** takes positive values for yellowish colors and negative values for the bluish ones. The sensor was standardized using a white and a black tile. Banana flake samples from 4.1 were placed in glass Petri dish. The measurement was performed in duplicate each consisting of ten readings and used to calculated mean values.

4.4 Sensory evaluation

The banana flake sample were scored on 9 point hedonic scale for appearance, color, flavor, crispness, taste, overall acceptance by 50 untrained panel. Each assessor tested all four samples in randomized order. Each sample was coded with three digit random numbers and both presented to the panelists. The panelists were asked to taste the sample from the left to the right. Hedonic scale was used by panelists to evaluate appearance, color, flavor, crispness, taste, overall acceptance. These attributes were rated on a 9-point hedonic scale wherein 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like a little, 5 = neither like nor dislike, 4 = dislike a little, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely.

4.5 Determination of water sorption isotherms and glass transition temperature

The banana flake samples from 4.1) were ground to 100 mesh size using a stainless steel blender with liquid nitrogen added to facilitate grinding. The adsorption isotherms and the glass transition temperature of banana flake powder were determined as explained in1.4.) and 2).

The equilibrium moisture data of banana flake powder were fitted using Guggenheim-Anderson-son-deBor (GAB) equation (Eq.3).

The models for predicting glass transition temperature (Eq.5 and Eq. 6) were used for fitting the experimental data of banana flake powder samples. The equation having height correlation coefficient (r) was selected as the best fit model.

5. <u>Effect of Storage Temperature on Qualities of Banana Flake.</u>

The banana flake product was formulated from 4) and the most suitable developed banana flake was selected for subjected to storage test. The banana flake products using completely randomized design: 4 temperature storage treatment. Banana flake products were put in aluminium foil bag (OPP30μ/ALU 7μ/LLDPE5μ, size 18.5x 15 cm.) 200 gram and were placed in incubator at -18, 23, 35, and 45°C for 0,10,20,… and 90 days. Physical, chemical and sensory properties of banana flakes were measured as these following.

5.1 Measurement of water activity in banana flake samples

Water activity (a_w) in banana flake products was measured by using the Novasina TH 200. Banana flake was crushed into small pieces and placed into measuring cups. The measurements were made at 25° C and continued until moisture equilibration was achieved, according to instrument specification.

5.2 Reducing sugar by Lane-Eynon Volumetric method A.O.A.C.(2000)

5.3 Physical properties determination of banana flake

Hardness and color properties of banana flake samples were determined as explained in section 4.3.1 and 4.3.2.

5.4 Sensory Evaluation

For the sensory analysis of banana flake, the profliling method based on quantitative descriptive analysis(QDA) method by Stone *et al.*, 1980 was used to generate descriptor. The evaluation was made by12 trained panels, who were used to establish the profiles of the banana flake during storage. Using the consensus vocabulary developed, intensity ratings were scored on a 15 cm. linear unconstructed scale anchored with the descriptors at side (e.g. not sweet on the left side and very sweet at the right side). In testing, an unstructured linear scale was used that covered the range 0 – 15 points, described at both ends. The testers marked their scores on a separate form. They experienced each samples, which were presented in random order and marked with 3-digit random codes. All four banana flake samples which stored at –18, 23, 35 and 45°C were assessed during each of testing sessions which were held after each storage period (0,10,20,30, …, 90 days). Ten-grams of banana flake were served in transparent container. All of the 12 panellists tasted all four banana flake at every session. At each sensory session the panelists judged four every 10 days. The performance of each panellist was expressed in terms of the correlation coefficient of that panellist's score with mean score of the whole group.

6. Consumer Testing

Three hundred students being 9-14 years old studied at elementary school and primary school in Phitsanulok province were selected as target consumer. Demographic information such as gender, age group, consumption frequency, acceptance test and preference test were asked in the questionnaire as sheen in Appendix Figure 2. Twenty five grams of banana flake were served consumer rated this acceptances of appearance, color, flavor, crispness, taste and overall acceptance using 9-point hedonic scales (1 = dislike extremely and 9 = like extremely).