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Moisture Sorption Isotherm Studies of Formulated Rice and Soy Based Ready – to – Eat Breakfast Cereals Using B.E.T Model

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Abstract

Satisfactory diets contain protein that is sufficient not only in quantity, but also in quality. A new type of combined breakfast blend based on locally available cereals and legumes were formulated adopting drum drying technology. Based on preliminary studies Soybean was maintained as 30-40% in the treatments while red rice was maintained as 60 - 70% in the treatments. Banana, pumpkin and milk powder were used as ingredients to overcome the beany flavour of the product. The prepared dried products were subjected to nutritional and sensory analysis. Based on the nutritional and consumer preference, the drum dried mixture of rice, soybean and banana was selected as best combination among the tested treatments. Moisture sorption isotherms for the best product were determined at 30 and 40°C over water activity range of 0.10 to 0.95 using a static gravimetric technique with the application of Brunauer–Emmett–Teller (BET) equations. The B.E.T monolayer values 5.23 and 5.12 g/ 100g dry matter were obtained from the constructed isotherm curves as this can be stored for a long term period at 30° and 40°C to meet the nutritional needs of the individuals.

Key words: B.E.T model, isotherm, moisture sorption, rice, soybean

Introduction

Developing countries feature a high cost of fortified nutritious proprietary balanced foods which are always, beyond the reach of most low income families. Such families often depend on inefficiently processed traditional foods consisting mainly of un-supplemented cereal foods made from rice, maize, sorghum and barley. Theoretically, there is enough food to feed the entire earth. Unfortunately, the balanced diet is not reached by each and everyone in the globe and simultaneously, chronic diet related diseases are also emerging as serious health problems in both developed and developing countries. Therefore, blending and appropriate processing of locally available food commodities have been carried out to improve nutrient density of the balanced food and improved nutrient intake, which have resulted in the prevention of malnutrition problems (Mariam, 2005).

Protein is a key nutrient needed by the body to build and repair tissue, provide structure, serve as an enzyme to begin cellular processes and form hormones. The Recommended Dietary Allowance (RDA) for sedentary individuals is 0.8 grams protein per kilogram body weight per day. Most people in developed countries (even vegetarians) are able to meet their protein needs through food (Fink et al., 2006). Good quality plant proteins have a significant role to meet the nutritional requirement of the fast growing population in developing countries like Sri Lanka. Grain legumes, like Soybean is an excellent source of protein (40-50%), hence seeds are the richest in food value of all plant foods consumed in the world. Soy protein products are an ideal source of essential amino acids used to complement cereal proteins. It is also rich in calcium, phosphorus, iron and vitamins (FAO, 2009). New prominence given on nutrition in breakfast cereals has meant more use of soy proteins to increase protein quality and quantity. Soy protein isolate in combination with wheat bran was used for the preparation of corn-based breakfast cereals extruded at varying feed moisture contents up to 25% and added sugar levels of 10% (Faller et al., 2000).

Most of the dried products are hygroscopic and the storage environment could adversely affect their quality. The shelf life and storage stability of foods are influenced by their moisture sorption characteristics (Baskaran et al., 2000). Thus, the study of moisture sorption characteristics of dried breakfast blend under various environmental conditions is essential. Knowledge of the moisture sorption characteristics is needed for shelf-life prediction and determination of critical moisture content for acceptability and storage of products.

The sorption characteristics are often represented by moisture sorption isotherms, which are plots of moisture content versus water activity at certain temperatures. They are the most effective and useful measurement of moisture in foods, with regard to microbiological growth and the determination of the physical attributes of foods. Moisture is held in hygroscopic materials by physical and chemical forces (Cenkowski et al., 1992) and the mechanism of moisture binding is affected by sorption characteristics of the material. The heat of sorption therefore provides useful information on the heat and free energy changes during moisture sorption processes in foods (Sopade and Ajisegiri, 1994). It enables the determination of the level of moisture content at which isosteric heat of adsorption approaches the heat of vaporization of pure water: i.e, it makes it possible to predict the moisture content below which additional energy will be required to remove bound water from the hygroscopic food substance.

Therefore, it is essential that efforts to formulate composite blends based on rice and soybean with the use of flavour cover-ups and carry out scientific studies to determine the nutritive adequacy as well as to determine the moisture sorption characteristics of these locally available cereal and legume blends to prolong storage and to be used as balanced foods, especially by the rural and low income urban families.

Methodology

Formulation of Composite Rice – Soybean Blends

The food commodities red rice and soybean flour, smashed sugar banana and pumpkin pulp and milk powder were taken based on their dry matter content, to formulate four composite blends to be used in this study. They were prepared as a paste by adding sufficient water and milled in a 2L mistral grinder. Then, these mixtures were dried by using the drum drier at a temperature of 140°C and a pressure of 40-60 lbs/inch^2 for 3mins and stored in airtight containers for further analyzes.

The composite flours of the four foods were formulated as follows:

- T_1 – Mixture of Rice and Soybean (70:30)
- T_2 - Mixture of Rice, Soybean and Banana (60:30:10)
- T_3 - Mixture of Rice, Soybean, Banana and Pumpkin (67:28:3:2)
- T_4 - Mixture of Rice, Soybean, Banana, Pumpkin and Milk powder (62:24:6:3:5)

Nutritional Analysis

The moisture, ash, protein, fat and fiber content of the dried products were determined according to the standard AOAC (2000) method while the total sugar was determined by Lane and Eynon method.

Sensory Analysis

Evaluation was done by using 30 trained panelists for colour, taste and overall acceptability of the samples by using ranking test. Samples were prepared by adding hot water to form a semi-solid mixture. Panelists were asked to rank the best samples according to the sensory properties and to add comments on their overall acceptability.

Statistical Analysis

The results were analyzed by Analysis of Variance (ANOVA) and the difference between means was compared using Duncan's Multiple Range Test (DMRT) through Statistical Analysis System (SAS) software statistical package.

Moisture Sorption Studies

Moisture sorption isotherms of formulate composite Rice – Soybean blends were determined at 30°C and 40°C using the static gravimetric method. The Brunaeur, Emmett and Teller (BET) model (Figure 1) was applied to fit the experimental data (Ait Mohamed et al., 2004). Seven salts were chosen (KOH, NaCl, KCl, NaOH, KI, KNO_3 and K_2SO_4) having a range of relative humidity of 5-90% to carryout the study. The experimental procedure involved using of seven glass jars of 1 liter each with an airtight lid. Every glass jar was filled to quarter depth with a saturated salt solution. Each glass jar with salt solution was immersed in a thermostat water bath adjusted to a fixed temperature for 24 hours to bring the salt solutions to stationary temperature.

Duplicate samples each of 0.01 g (±0.001g) for adsorption were weighed and placed in glass jars containing saturated salt solution. The equilibrium was judged to have been attained when the change in subsequent readings was less than 1 mg. The moisture content of each sample was then determined by the oven-drying method at 105°C for 24 h (Ait Mohamed et al., 2004).

Analysis of Moisture Sorption Data

The general equation for the B.E.T isotherm model:

$$\frac{aW}{(1-aW)\,m} = \frac{1}{M_0 c} + \frac{c-1}{M_0 c} \times aW$$

Where: aW – Water activity
m – Moisture content (dry weight basis) at water activity
M_0 – Monlayer value
c – Constant

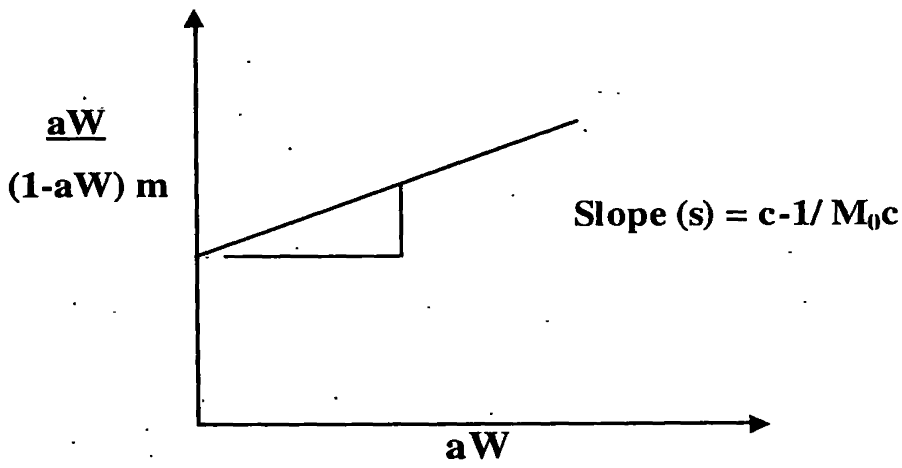


Figure 1: B.E.T plot for Determination of the Monolayer Value

Calculation of Monolayer Value

$$\frac{aW}{(1-aW)\,m} = \frac{1}{M_0 c} + \frac{c-1}{M_0 c} \times W$$

$$\frac{aW}{(1-aW)\,m} = i + s.\,aW$$

$$M_0 = \frac{1}{i+s}$$

i – Intercept
s - Slope

Results and Discussion

Comparison of Nutritional Properties

The overall results indicated that protein, fat, fiber, ash, moisture, total sugars and total soluble carbohydrates are comparable among all the treatments which are shown in Table 1.

Table 1: Nutritional Composition of the Rice-Soy based Blends

Components	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
Protein	18.6±0.01bc	17.4±0.01b	12.6±0.02a	16.8±0.07b
Fat	6.70±0.01a	6.32±0.06a	6.04±0.01a	12.0±0.01b
Total Soluble Carbohydrate	66.4±0.03a	65.9±0.02a	70.6±0.01ab	62.2±0.03a
Fiber	0.90±0.01b	0.87±0.01b	1.11±0.05bc	0.34±0.01a
Ash	2.86±0.04b	2.94±0.03bc	3.21±0.01c	1.95±0.05a
Moisture	3.90±0.02bc	3.12±0.01a	4.14±0.02c	3.68±0.02b
Total sugars	0.65±0.01a	3.36±0.02b	2.27±0.01bc	2.94±0.04bc

*Values are means of triplicates ± standard errors
T_1 – Mixture of Rice (70%) and Soybean (30%); T_2 – Mixture of Rice (60%), Soybean (30%) and Banana (10%); T_3 – Mixture of Rice (67%), Soybean (28%), Banana (3%) and Pumpkin (2%); T_4 – Mixture of Rice (62%), Soybean (24%), Banana (6%), Pumpkin (3%) and Milk powder (5%).

Treatments 1 and 2 contained high amount of protein of 18.6 and 17.4% than the treatments 3 and 4 (12.6 and 16.8%). The high proportion of incorporated soy flour in T_1 and T_2 increased the amount of protein in the dried samples. Lang (1999) showed that most applications for de-fatted soy flours involve their combination with cereals and their addition raises both the quantity and quality of the protein in cereal products. The quality of the protein is improved in soy–cereal mixtures because soy protein is a rich source of lysine. The processing of soybean would improve the quality of the protein, in general, and therefore, processing methods used in the preparation of the mixtures enhance the protein quality of the final product (Mariam, 2005).

The fat content was high in T_4 (12%) where the addition of milk powder increased the amount of fat content in the sample compared to other samples. This is also supported by Yetley and Park (1995), where the addition of the milk increases the fat content in the food products. Total sugars were high in T_2 (3.36%), where the incorporated banana pulp was high in proportion (10%) compared to other treatments. Studies showed that banana pulp acts as cover-up and as well as source of sugars up to 24% (Horti et al., 1999). In contrast, lowest value was observed in the mixture of rice and soybean flour blend (T_1).

The highest value of total soluble carbohydrate was obtained in T_3 and the second highest was in T_1 where the proportion of banana pulp and rice flour was higher than the other treatments, respectively. Rice contributes the major portion of carbohydrates and it is higher in T_1 and T_3 as 70% and 67%. Treatment 3 contained high amount of fiber, moisture and ash among all other treatments. Studies showed that rice and soybean contribute a major portions of nutrients in the legume based cereal mixture which is supported by Breena (2001) whereas, banana contains high amount of vitamins and minerals especially potassium (Butters and Richard, 2004) and it is also used as a low fat diet from a nutritional point of view.

Organoleptic Evaluation

Sensory analyzes were made for colour, taste and overall acceptability of the samples. Scores were subjected to ANOVA to find out the significant differences between the samples. Taste is the primary factor which determines the acceptability of the products which has the highest impact as far as market success of the product is concerned. Based on the consumers' ranking, 62.5% of the panelists selected the blend containing the rice, soyabean and banana (T_2) as the best product while, 50% of the panelists selected the T_4, which contained milk powder in addition to the other ingredients, among the other treatments.

Based on the consumers' results, T_2 has the highest mean score for taste among the others and T_1 had the lowest score. This is due to the beany flavour of soybean. Studies showed that banana acts as a cover-up in beany flavour products and T_2 has the highest percentage of banana pulp. However, colour didn't show any significant differences among the treatments. All the formulated samples were yellow in colour. Pumpkin did not influence in any of organoleptic characters among the treatments.

Moisture Sorption Studies and B.E.T. Monolayer Values

The monolayer value is important because it facilitates to find out the ideal safe moisture content to store the product for a long period of time and to ensure a microbial free product for human consumption. Normally, water activity influences the deteriorative reactions such as hydrolysis, oxidation, browning during processing and storage of foods and food products. The sorption isotherms give the characteristic S-shaped curve, which is typical for many plants and foods materials (Lahsasni et al., 2003).

Figure 2 shows the isotherm curves at the temperatures of 30° and 40°C for the rice – soybean– banana blend.

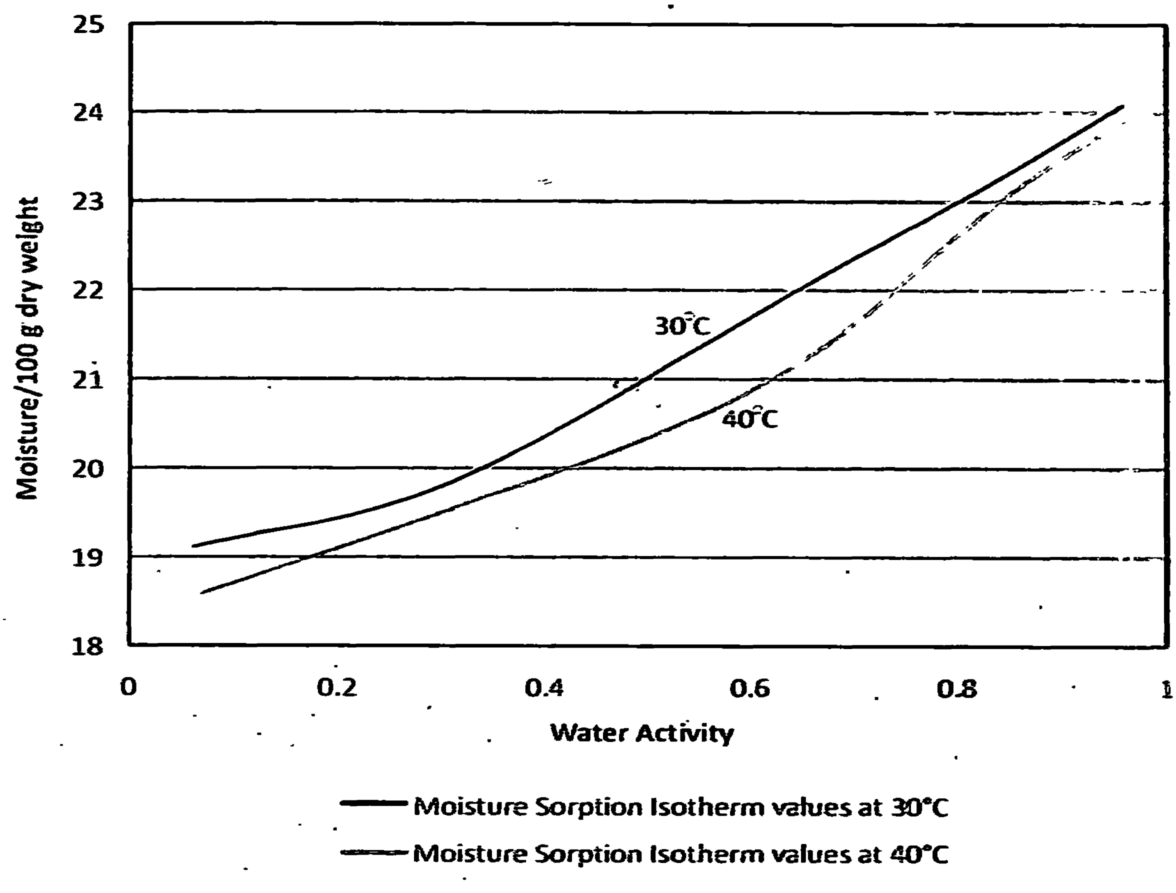
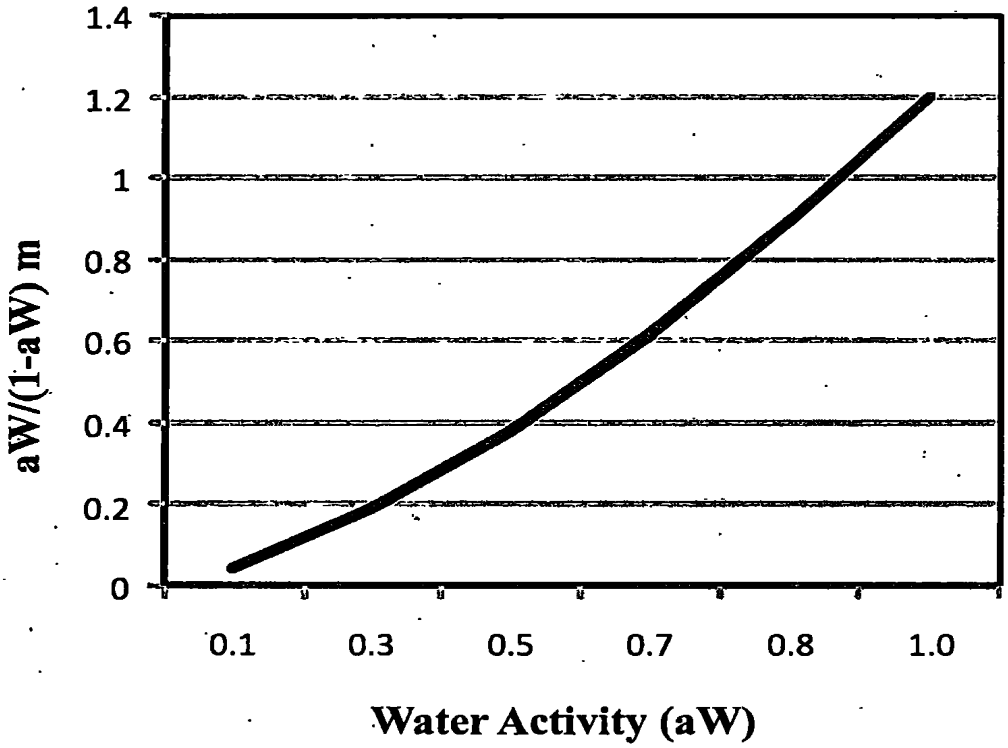


Figure 2: Moisture Sorption Isotherm Curves at 30° and 40°C

Farther it shows a significant temperature effect on the adsorption for the full range of water activities for this product. The equilibrium moisture content increases with decreasing temperature at constant relative humidity; this may be due to the fact that these changes are caused by the inability of the foodstuff to maintain vapour pressure at unity with decreasing moisture content which is supported by Lopes Filho et al., (2002). An increase in temperature at fixed moisture content tends to lower the isotherm curves, increase in water activity increases the product's susceptibility to microbial spoilage (Labuza et al., 1985).

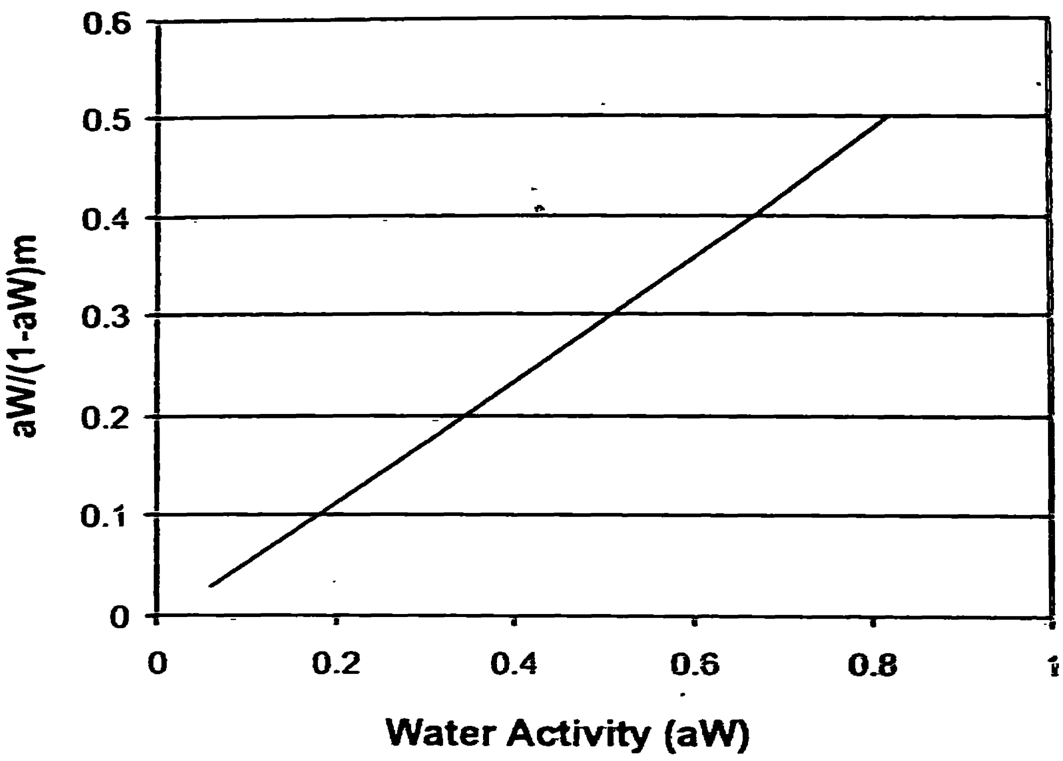
From the kinetic molecular theory, it could be argued that as the temperature is increased, sorbed molecules gain kinetic energy and high degree of freedom, which promotes escape of water from the sorbent surface. This causes the amount of sorbed water to decrease with increase in temperature (Karel, 1975). Several researchers observed an increase in water activity with an increase in temperature in defatted pumpkin seed flour (Menkov and Durakova, 2005), bean powder (Menkov et al., 2005) and Irish potato (Wang and Brennan, 1991). They assumed that when the temperature increased, the structure and constituent of the materials were affected resulting in surface plasticization and reduction in sorption sites; and hence the reduction in the equilibrium moisture contents.



B.E.T. Monolayer from Figure: 3.

Intercept (i) = 0.03
Slope (s) = 0.1667
Mo = 1/ (i+s) = 5.23g moisture/ 100g dry weight

Figure 3: Values for B.E.T. monolayer plot for the dried product at 30°C



B.E.T. Monolayer from Figure: 4.

Intercept (i) = 0.0175
Slope (s) = 0.1778
Mo = 1/ (i+s) = 5.12g moisture/ 100g dry weight

Figure 4: Values for B.E.T. monolayer plot for the dried product at 40°C

From the figure 3 and figure 4, the equilibrium monolayers moisture contents of the rice, soybean and banana blend was 5.23 and 5.12 g H_2O/100 g dry matter at 30 and 40° C respectively. This implies that at any relative humidity, dried breakfast blend became less hygroscopic with an increase in temperature.

It was observed that the equilibrium moisture content (sorbed water) increased as water activity increased at constant temperature. These results indicate that at low water activities, less water was available for adsorption by the material. From the above the monolayer values of prepared samples were 5.23 and 5.12g/100g dry matter product at 30° and 40°C, respectively. Therefore, the above moisture levels at 30° and 40°C were ideal for the prepared blend (mixture of rice, soybean and banana) to store safely for a longer period of time. Above this equilibrium relative humidity, a marginal increase in water activity would cause a significant increase in the amount of water adsorbed and would accelerate deterioration.

Conclusions

This study revealed that the complementary food products formulated from locally available food commodities, can meet the macro nutritional needs of human. Four composite blends were formulated based on protein basis of the food commodities used. The study was carried out to introduce a protein rich new type of breakfast cereal. Rice flour was incorporated with soybean flour for protein enrichment and banana, pumpkin and milk powder as cover-ups. Nutritional, sensory and moisture sorption behavior were analyzed during the study period. Based on the above analysis treatment 2 (mixture of rice, soybean and banana) was selected as best treatment which contains 17.4% of protein, 6.32% of fat and 3.36% of total sugars with high overall acceptability. The B.E.T monolayer value of the T_2 (mixture of rice, soybean and banana) at 30° and 40°C were 5.23 and 5.12 g water / 100g dry matter respectively, for long period storage at particular temperatures.

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