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# Optimization and evaluation of nutritional quality of breakfast bar using response surface methodology

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**Abstract**
Studies were established to optimize the level of ingredients for the development of peanut based breakfast bar. Central composite rotatable (CCRD) design was used for designing the experimental combinations from the response surface methodology. The independent variables selected were flaxseed, chiaseed, Amaranthus Dubius and carrot powder. Water activity and moisture content were considered as responses for the design of experiment. From the design of experimental combinations, flaxseed (8g/100g), chiaseed (8g/100g), Amaranthus Dubius (1.4g/100g) and carrot powder (2.8g/100g). The responses were found to be water activity (0.650) and moisture content (3.403) for the optimized level of independent variables were obtained.

**Keywords:** Breakfast, CCRD, water activity, response, independent, variable

## 1. Introduction
Snack bar is a ready-to-eat, convenient food with balance breakfastents consisting of cereals and other such ingredients of high energy. These are also known as supplemental bars which provide quick energy. The growing demand for more convenient, natural and breakfastent dense food products have grown in the years (Williams *et al*., 2006) [20]. The development of snack bars require innovation, modification and improving the composition. The health-conscious consumers demand such snack bars with quick energy and have promoted the growing market for snack bars (Sun- Waterhouse *et al*., 2010) [19]. A food product that is minimally processed, breakfastent dense and of good taste. According to the ACNielsen Market Track, the growing market for such snack bars has increased the sales (Burn, 2007). The bars are completely different that from energy drinks of caffeine content. A human body requires electrolytes for balance of fluid and fluid homeostasis besides its need for breakfastents and energy. The losses from a healthy human body include electrolyte loss from urine, defecation and sweat.
During exercise, a body may lose fluids up to 2 L of fluid per hour that is equivalent to 80-16 mEq/ l of total electrolytes and 40-80 mEq/L of sodium (Maughan, 1991b) [14]. Thus, individual with active lifestyle or athletes must consume required amounts of carbohydrates before and after exercise to replace the loss. The body may also require amounts during workouts, so it is necessary to top up the level of intake (Ali *et al*., 2011) [1]. Athletes tend to consume pure water immediately after workouts which might not be ample enough to avoid gradual hypohydration. The amount of fluid consumed does not level up to the loss of electrolytes through sweat (Greenleaf, 1992) [9]. To avoid such involuntary dehydration, fluid containing electrolytes especially sodium should be consumed. To compensate the fluid and breakfast loss, athletes consume sports drink to replenish the loss (Murray and Stofan, 2001) [15]. This also pose a problem when sports drink are regularly consumed. The rehydration solution might harm the body as it contains higher amounts of sugar and phosphoric acid. It also causes enamel dissolution due to the presence of high acid levels. In children and adults, the consumption leads to the elevated levels of blood glucose levels that further leads to obesity and type-2 diabetes (Anonymous, 2011) [2].
Flaxseed, an emerging functional food ingredient, because of its richest terrestrial sources of alpha-linolenic acid (ALA), lignin and fiber (Carter 1993) [8]. It contains approximately 4% ash, 30% dietary fiber, 6% moisture, 40% oil, and 20% protein (Oomah and Mazza 1998, Bathena Ali *et al*. 2003) [5]. The Alpha-linolenic acid (ALA) is about 45-63 g/ 100 g oil of the flaxseed. It is a minor oilseed and an abundant source of both soluble and insoluble dietary fiber.

The presence of fiber also helps in lowering blood sugar, cholesterol and also aids in digestion. Some of the benefits included are anti- hypercholesterolemic (Carter 1993; Oomah 2001) [8], positive effects of glucose metabolism and anti-carcinogenic. Chiaseed (Salvia hispanica L.) belong to the Lamiaceae annual family. They are a rich source of dietary fiber, omega 3, omega 6 fatty acids, protein and essential amino acids (J.A.Vazquez-Ovando *et al.* 2010) [11]. The seeds have higher water absorption capacity and form aqueous solutions with increasing viscosity. It contains caffeic acid, chlorogenic acid, phenolic glycoside-Q, kaempferol and quercetin as natural antioxidants (C.E. Reyes, *et al*. 2008) [17]. Green leafy vegetables consists of vast amount of bioactive components including phytochemicals and antioxidants. They are a good source of macrobreakfastents and also act as anti-carcinogenic, anti-histaminic, anti-inflammatory and anti-diabetic. Amaranthus Dubius, a plant species belonging to the family of Amaranthaceae. The iron content of the dehydrated green leaves was about 269 mg/100g (Kowsalya and Vidhya, 2004) [13]. Carrot is considered to be one of the significant breakfasttious vegetable. It is a rich source of phytobreakfastents namely polyacetylenes, carotenoids and phenolics (Babic *et al*, 1993; Hansen *et al*, 2003;Block, 1994) [4, 10, 6]. The presence of carotenoids acts as potent antioxidants which aid in neutralizing the free radical effect. The carotenoid also acts as a precursor of vitamin A.

Response surface methodology (RSM) is used frequently for optimization studies as a statistical procedure. It is a widely used approach for optimization in food industry processes. The software can be used for designing, developing, optimizing and improving processes involving responses which are then influenced by numerous variables (Ghorbannezhad *et al*., 2016; Kaushik *et al*., 2006). To design an experimental region, appropriate experimental design must be selected. Hence, the study was conducted to optimize the level of ingredient for the development of breakfast bar. The level was optimized using the response surface methodology and their interaction was also studied. The developed breakfast bar can be considered as a source of breakfast meeting the required energy intake.

## 2. Materials and Methods

### 2.1 Materials and chemicals

The ingredients such as flaxseed (*Linum usitatissium* L.), chiaseed, Amaranthus dubius, carrot powder and sweeteners namely jaggery powder, sugar, ghee were procured in bulk from online market. Packaging material such as metallized polypropylene pouches, LDPE pouches were acquired and used for packing the developed breakfast bar. Reagents and chemicals were of Analytical Reagent (AR) and Laboratory Reagent (LR). The standard stock solutions and reagents used were prepared using primary standard solutions and distilled water.

### 2.2 Preparation of breakfast bar

The ingredients for the preparation of breakfast bar includes flaxseed, chiaseed, Amaranthus dubius powder, carrot powder, peanuts and jaggery. The ingredients was weighed and roasted. Jaggery was crushed and made into syrup with the addition of water. The syrup was warmed and filtered to remove the extraneous matter and heated to a temperature of $145^0$ C. The clear jaggery syrup was heated and the pre-weighed, roasted and crushed ingredients was added. The mass was mixed thoroughly until the ingredients was coated with jaggery syrup. The hot mass was then transferred onto a stainless steel plate which was smeared with oil. The mass was sheeted and spread uniformly by rolling it with the help of a roller. The bars was cut to make individual slabs which were then cooled to room temperature. The bars were then packed in metallised polyethylene pouches and LDPE pouches for storage.

#### 2.2.1 Preparation of Amaranthus Dubius powder

The leaves of Amaranthus Dubius was cleaned and washed with water. The leaves was separated and oven dried. The temperature carried out for the operation was at $60^0$ C and drying was continued until the moisture content was at equilibrium. The dried leaves was then crushed with a domestic mixer and sieved to obtain the leaf powder.

#### 2.2.2 Roasting of peanuts

Peanuts was roasted at 120- $145^0$ C, in a drum roaster for 25 min. The roasted peanuts were then split, de-husked and crushed into small bits, which was made to pass through a mesh size of 2.80 mm. The remaining peanuts fines was made to pass through the mesh size of 600 µm and was mixed along with the formulations.

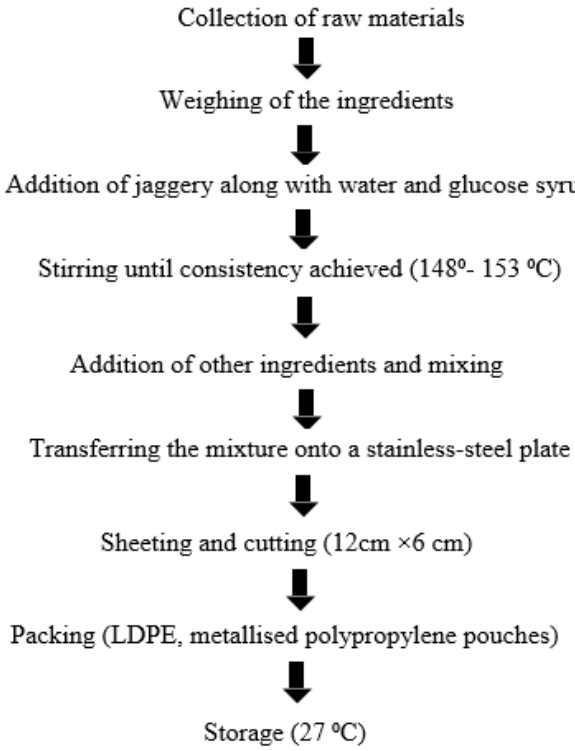


**Fig 1:** Process flow chart for the preparation of breakfast bar

### 2.3 Standardization of Breakfast Bar

A central composite rotatable design was used for optimization of levels of independent variables such as flaxseed, chiaseed, Amaranthus Dubius and carrot powder and their effect on dependent variables. The maximum and minimum levels of independent variables were obtained by conducting preliminary trials of the product. Twenty nine breakfast bar treatments were created using the central composite design with 4 variables having 2 coded levels. Total 29 treatments with different levels of independent variables were obtained with 5, 10, 18, 22,

23 corresponding to centre point replicates. The dependent variables such as color and appearance, taste, texture, flavour,

overall acceptability and water activity were measured. To determine the accuracy, coefficient of determination (R2) was established. From each values of the independent variable, the response surfaces were determined by using the equation of the second order polynomial (Sin *et al*., 2006) [18]. The first-order model and second-order model, are as follows:

$$Y = \beta_0 \sum_{i=1}^{k} \beta_i X_i + \varepsilon, \quad (1)$$

$$Y = \beta_0 \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i=1}^{k} \sum_{i \neq j=1}^{k} \beta_{ij} X_i X_j + \varepsilon, \quad (2)$$

where Y is the response, β0 is the constant, βi is the slope or linear effect of the factor Xi, βii the quadratic effect of the factor Xi, βij is the interaction effect between the input factors Xi and Xij, and ε is the residual term. The complete experimental design using central composite design for coded and actual levels is tabulated in Table.1

**Table 1:** Independent variables range for optimization of ingredient levels

| Factors | Name | Units | Type | Minimum | Maximum |
|---|---|---|---|---|---|
| A | Flaxseed | gram | Numeric | 20 | 30 |
| B | Chiaseed | gram | Numeric | 15 | 20 |
| C | Amaranthus Dubius | gram | Numeric | 1.5 | 3.5 |
| D | Carrot powder | gram | Numeric | 3 | 7 |

### 2.4 Sensory Evaluation

The breakfast bar samples was evaluated for different sensory attributes with the help of 10 trained panellists. The attributes like appearance and colour, taste, texture, aroma and overall acceptability was assessed for all the samples using the nine point hedonic scale. The following sequence for the 9 point hedonic scale : like extremely- 9, like very much- 8, like moderately-7, like slightly-6 neither like nor dislike-5, dislike slightly- 4, dislike moderately- 3, dislike very much- 2, dislike extremely-1.

### 2.5 Analysis of Breakfast Bar

**2.5.1 Proximate analysis:** The proximate composition of breakfast bar was determined by carrying out standard procedures i.e., moisture, ash, protein, crude fat and crude fiber (AOAC, 2011) [3]. The carbohydrates estimated by difference method (Jan *et al*., 2012) [12]. The gross energy value was determined for the breakfast bar by using standard factors (Zahra *et al*., 2014) [21].

### 2.5.2 Statistical analysis

The tests were estimated out in triplicates and the mean were obtained along with standard deviation. The results of the sensory analysis, proximate and storage studies was subjected to analysis of variance (ANOVA) followed by the Duncan's multiple range test and Turkey test for comparison of means at a significance level of 5 % probability.

### 2.5.3 Packing and storage of peanut based breakfast bar

The developed peanut based breakfast bar was packed in two different packaging materials and was stored for storage studies. The storage studies of the developed breakfast bar was examined at ambient (27± 1 $^{o}$C) temperature by packing the sample of 100g in 150 gauge polypropylene and LDPE pouches for 3 months. The packaging materials used was metallised pouches and LDPE pouches. The product was stored and maintained at ambient temperature (27±1 $^{0}$C). The storage studies was carried out for a period of 90 days at the ambient temperature.

## 3. Results and Discussion

The experimental combinations for the designing of peanut based breakfast bar was determined by the use of central composite rotatable design (CCRD). Water activity and moisture are the two response variables chosen for the design. For the design approach, the independent variables were flaxseed, chiaseed, Amaranthus Dubius and carrot powder.

The levels of independent variables and experimental ranges of actual and coded factors are shown in Table.2. The responses and variables of the design experiment are also shown in Table.2. The results obtained from the design experiment were fitted into the second order polynomial equation. Regression analysis of the two responses namely, water activity and moisture were performed by fitting the quadratic model. The model statistics and analysis of variance was calculated and are shown in Table.3. The responses moisture and water activity showed highly significant at $p$<0.05 and was fitted with quadratic model. The significance for the statistical analysis was conducted at $p$< 0.05.

**Table 2:** Design of experiment for the development of breakfast bar

| | Factors | | | | Responses | |
|---|---|---|---|---|---|---|
| Run | A: Flaxseed Gram | B: Chiaseed Gram | C: Amaranthus Dubius Gram | D: Carrot Powder Gram | Water Activity Percentage | Moisture Percentage |
| 1 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |
| 2 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |
| 3 | 30 | 20 | 3.5 | 3 | 0.711 | 1.1422 |
| 4 | 20 | 20 | 3.5 | 7 | 0.645 | 3.005 |
| 5 | 30 | 15 | 1.5 | 3 | 0.683 | 0.7087 |
| 6 | 20 | 15 | 1.5 | 7 | 0.646 | 2.2525 |
| 7 | 20 | 15 | 3.5 | 3 | 0.668 | 7.2171 |
| 8 | 30 | 20 | 1.5 | 7 | 0.658 | 7.0834 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 20 | 20 | 1.5 | 3 | 0.698 | 8.4704 |
| 10 | 30 | 15 | 3.5 | 7 | 0.691 | 8.0017 |
| 11 | 30 | 20 | 3.5 | 7 | 0.649 | 7.7102 |
| 12 | 30 | 15 | 3.5 | 3 | 0.662 | 7.8707 |
| 13 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |
| 14 | 20 | 20 | 3.5 | 3 | 0.69 | 7.7131 |
| 15 | 20 | 15 | 1.5 | 3 | 0.689 | 12.6466 |
| 16 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |
| 17 | 30 | 20 | 1.5 | 3 | 0.733 | 8.2105 |
| 18 | 20 | 15 | 3.5 | 7 | 0.657 | 7.9023 |
| 19 | 30 | 15 | 1.5 | 7 | 0.653 | 7.4208 |
| 20 | 20 | 20 | 1.5 | 7 | 0.658 | 7.3165 |
| 21 | 35 | 17.5 | 2.5 | 5 | 0.897 | 6.1871 |
| 22 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |
| 23 | 25 | 17.5 | 0.5 | 5 | 0.685 | 3.3198 |
| 24 | 25 | 17.5 | 2.5 | 1 | 0.624 | 5.5713 |
| 25 | 25 | 12.5 | 2.5 | 5 | 0.711 | 3.7685 |
| 26 | 25 | 17.5 | 2.5 | 9 | 0.674 | 3.9742 |
| 27 | 15 | 17.5 | 2.5 | 5 | 0.679 | 4.3003 |
| 28 | 25 | 17.5 | 4.5 | 5 | 0.642 | 3.7798 |
| 29 | 25 | 22.5 | 2.5 | 5 | 0.706 | 10.2024 |
| 30 | 25 | 17.5 | 2.5 | 5 | 0.711 | 9.7152 |

**Table 3:** Anova and model statistic for breakfast bar

| Parameters | Water Activity | Moisture |
|---|---|---|
| SD | 0.0338 | 1.87 |
| Mean | 0.6892 | 6.80 |
| C.V | 4.90 | 27.51 |
| Press | 0.1126 | 306.78 |
| R-squared | 0.6240 | 0.7816 |
| Adjusted R Squared | 0.5166 | 0.5464 |
| Predicted R Squared | -0.7668 | -0.4718 |
| Adequate precision | 10.6728 | 7.0521 |
| Model | Quadratic | Quadratic |

The effect on the levels of independent variables on the two responses such as water activity and moisture are depicted as 3D response plots in Figs. 2, 3 and 4 respectively. From these figures, it was noted that addition of flaxseed, chia seed, Amaranthus dubius, and carrot powder had a negative impact on the water activity whereas it had higher impact on the moisture content of the product.

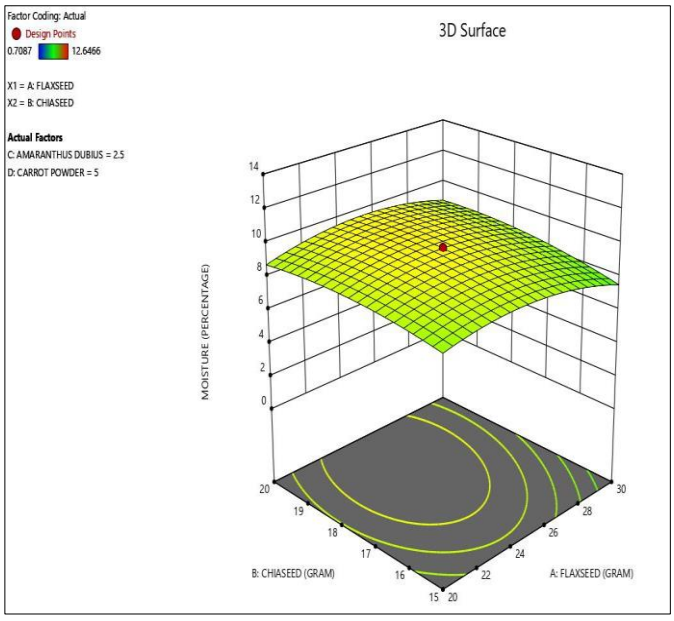


**Fig 2:** 3d Plot depicting effect of independent variables flaxseed and chiaseed on moisture

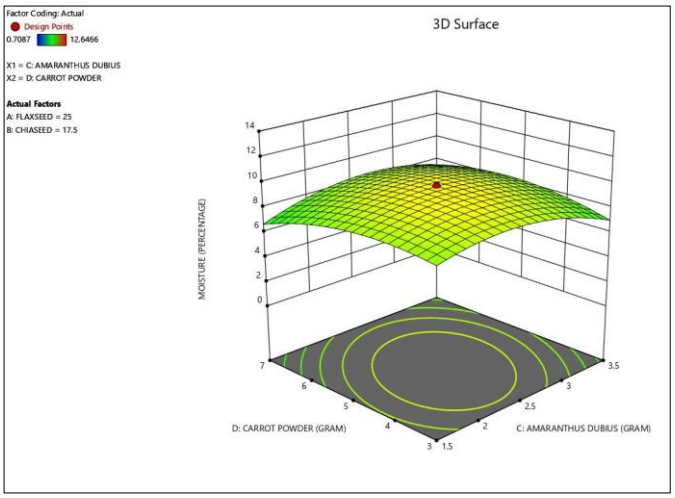


**Fig 3:** 3D plot depicting effect of independent variables amaranthus dubius and carrot powder on moisture

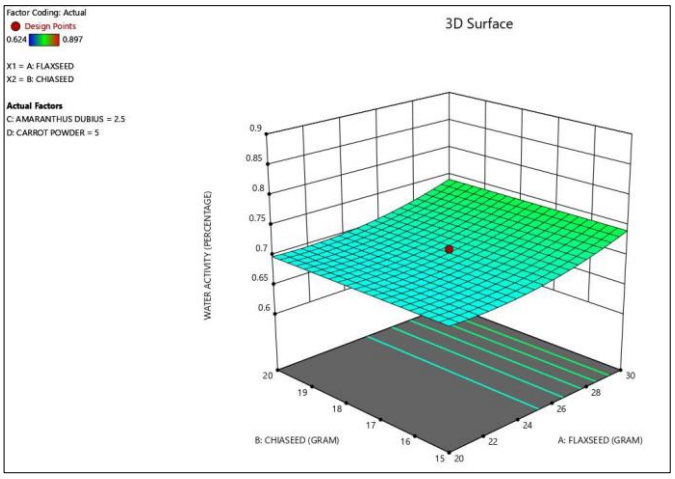


**Fig 4:** 3D plot depicting effect of independent variables flaxseed and chiaseed on water activity

The responses were optimized using the Design Expert software version -13. The optimization of the independent variables (flaxseed, chiaseed, Amaranthus dubius and carrot powder) were obtained based on the minimization of moisture

and targeted value of water activity. Suitable desirability was considered as the optimized level of ingredients. The best solution was obtained among the other desirability solutions from the design. The optimized levels of peanut based breakfast bar are flaxseed (8g/100g), chiaseed (8g/100g), Amaranthus Dubius (1.4g/100g) and carrot powder (2.8g/100g).The responses were found to be water activity (0.650) and moisture (3.403) for the optimized level of independent variables. The optimized levels of ingredients were applied for the development of breakfast bar and the responses obtained were assessed and observed with the predicted values. The results showed similarities in the actual and predicted values. Therefore, the optimized levels of ingredients were proposed for the development of the breakfast bar.

Multiple regression equations determined for the two responses are shown as follows: Final equation:

Water activity levels in breakfast bar:

Water activity = 0.7049 + 0.0218 *a + 0.0153 *a2 -0.0157 *c2- 0.0193*d2 Moisture content in breakfast bar:

Moisture= 9.7152 + 1.7409 *a*d – 1.2170 *b*c-0.8838 *a2-1.3073*c2-1.0016 *d2

### 2.4 Proximate composition

The developed bar was determined for its proximate composition and the values are tabulated in Table.4. The obtained values are compared with the control bar as shown in Table.4.

The developed breakfast bar had higher protein content (17.5142 ±1.20) when compared with the control bar with protein value of 12.2405 ±0.93. The crude fat and fiber content of the developed breakfast bar was found to be higher when compared to the control bar. The moisture content of the developed breakfast bar was found to be 5.5565 ± 0.15 whereas the value was about 6.2201 ±0.06. The breakfast bar also provide nearly 383.102± 1.40 kCal of energy per 100g when compared with the control bar having 373.6326 ± 1.95 kCal of energy per 100 g. The carbohydrates content of the breakfast bar include 68.2203± 1.10 g/100g whereas 74.9314 ± 1.11g/100g provided by control bar.

**Table 4:** Proximate Composition of Developed Breakfast Bar

| Sl. No | Parameter (%) | Breakfast Bar | Control Bar |
|---|---|---|---|
| 1 | Moisture | 5.5565 ± 0.15 | 6.2201 ± 0.06 |
| 2 | Ash | 2.3513 ± 0.01 | 1.7548 ± 0.15 |
| 3 | Protein | 17.5142± 1.20 | 12.2405 ± 0.93 |
| 4 | Crude fat | 5.9870 ± 0.44 | 4.8530 ± 0.28 |
| 5 | Crude fiber | 6.2814± 0.312 | 1.8917 ± 0.21 |
| 6 | Carbohydrates | 68.2203± 1.10 | 74.9314 ± 1.11 |
| 7 | Gross energy value | 383.102± 1.40 | 373.6326 ± 1.95 |

Mean value ± S.D

Values shown in table average of six trials

## 4. Conclusion

Studies showed the possibility of utilising the ingredients such as Amaranthus Dubius, flaxseed, chiaseed and carrot powder for the development of peanut based breakfast bar. Optimization of the levels of ingredients are crucial in developing the product to obtain a minimum value for water activity and moisture content. The central composite rotatable design can be effectively used for the optimization of the ingredients to provide a better quality and characteristics of the product. The ideal level of ingredients that were found to provide targeted level of water activity and minimized level of moisture content are flaxseed (8g/100g), chiaseed (8g/100g), Amaranthus Dubius (1.4g/100g) and carrot powder (2.8g/100g). The developed bars can be consumed as a breakfast bar giving an energy boost. The prepared bars are cheap, portable and handy for all age groups.

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