Physicochemical and sensory characteristics of no-bake wheat–soy snack bars

Fadi M Aramouni\textsuperscript{a} and Mahmoud H Abu-Ghoush\textsuperscript{b,∗}

Abstract

BACKGROUND: Health and wellness is a trend observed throughout ready-to-eat cereals, cereal health bars. Therefore, the main objectives of this research were to produce a low cost, acceptable, nutritious and healthy wheat- and soy-based bar under no-bake conditions. Also, the physical, chemical, microbial, acceptability and the nutritional value of this product were studied. Six different bars were produced: a wheat bar (WB), a wheat bar with coating (WBC), a wheat and soy bar with coating (WSBC), a soy bar with coating (SBC), a wheat bar with 3% glycerin (WB3%), and a wheat bar with 6% glycerine (WB6%).

RESULTS: WB and WBC had the highest water activities while WSBC had the lowest. The three bars with coating had higher L and lower b values, which indicates that they were lighter and not as highly coloured as the wheat samples. WSBC had the lowest value for hardness while the SBC and WBC had the highest. SBC received the highest scores for overall acceptability, appearance, sweetness, flavour and texture while WSBC received the second highest score in all categories.

CONCLUSION: It appears that consumers prefer the soy varieties to the wheat bars. These types of bars can aid in feeding the general population, which is becoming increasingly concerned with nutrition and convenience.

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Keywords: wheat-soy bars; no-bake bars; sensory acceptability

INTRODUCTION

The term ‘nutritional bar’ covers a wide array of products. Nutritional bars include energy bars, meal replacement bars, and low-carbohydrate bars. Additionally, there are cereals, nutraceutical, diet, and snack bars along with bars targeted to the nutritional needs of diabetics, women and children.\textsuperscript{1} These nutritional bars are often made using a base of grains, such as rice or oats, or proteins, such as soy or whey.\textsuperscript{2} The bars are often fortified using a wide range of vitamins, minerals, herbs and other nutrient- or energy-rich ingredients. The base flavouring of these bars originally trended more towards chocolate and peanut butter, but the current trend is more towards variety and sophistication, both to attract consumers and to differentiate products in the marketplace. New bar varieties developed include apple crisp, raspberry cheesecake, and chocolate almond coconut.\textsuperscript{2}

Nutritional bars have become a solution for lunch boxes, fast on-the-bus breakfasts, and after-school snacks.\textsuperscript{3} Bars are not just popular because of their portability, however. They have also become popular because of the health connotations associated with them. Health and wellness is a trend being marketed by the general population, which is becoming increasingly concerned with nutrition and convenience.\textsuperscript{4}

Whole-grain products, specifically wheat products, have grown in popularity as part of the health and wellness trend. Whole-wheat products in particular are ‘a source of dietary fibre, an indigestible carbohydrate that yields little or no energy but appears to play a role in preventing some types of cancer.’ The rise in consumption of the grain is echoed in the U.S. Department of Agriculture and Health and Human Service’s Dietary Guidelines for Americans, which ‘stress[es] the need for six to 11 servings of grain products (breads, cereals, rice and pasta) each day’.\textsuperscript{5} The guidelines suggest that adults ‘consume three or more one-ounce equivalents of whole grain products per day, with the rest of the recommended grains coming from enriched or whole grain products’.\textsuperscript{6} While soy is not a grain, it too has been recognised as providing a variety of potential health benefits.

While convenience and health benefits are important factors to consumers, products will not remain marketable for long if they do not offer a satisfactory taste. In a sensory study, it was found that ‘the majority of consumers ranked ‘taste’ as the most important characteristic influencing their purchase intent’.\textsuperscript{7}

In 1999, the snack bar market, which includes all breakfast, nutrition, and granola bars, hit $1 billion. The largest component of the market was nutrition bars, which represented nearly half of the total sales.\textsuperscript{8} Between 2004 and 2009, the expected growth rate of that market is 7.6%.\textsuperscript{8} The growth of the snack bar market is not only found in the United States, but in other regions of the world as well. Business Trend Analysts Inc. found that sales of cereal bars in Argentina grew by more than 160% in 2000. This growth is expected to continue at 30% per year for the next several years.\textsuperscript{9}

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With the updated US food pyramid and the ongoing publicity surrounding obesity, health and wellness will remain a top trend for nutritional bars in the US. Therefore, we expect to see whole grains continue to play a large role in the market as well as a continuing trend toward low-carbohydrate consumption.4 With regard to flavours, more fruit is expected, as well as more indulgent flavours throughout the cereal and nutritional bar markets.4

Nutritional bars are not only convenient and healthy for people on-the-go but are also a compact way to ship energy and vitamin foods to people in famine-stricken areas of the world.

These bars must have pleasing flavours, textures and nutritional advantages that will allow them to compete among other varieties already on the market. Therefore, the main objective of this research was to produce low-cost, acceptably flavoured, nutritious bars to enhance the sweet flavours and to increase browning.11 In addition, glycerin can make the bars smoother, richer, moister and fresher. It plays an important role in bars by adding humectancy and reducing water activity in these bars. Also, some sweeteners such as corn syrup and brown sugar were added to the bars to enhance the sweet flavours and to increase browning.11

Preparation of the bars was subdivided into two main stages according to the ingredients added. The first stage included adding water, corn syrup, glycerin, brown sugar, gum Arabic, Panodon 150K, vanilla extract, and shortening (all of which were weighed) to a 3-quart metal pan. In the second stage, depending on which bar is made, ingredients were weighed and some or all of the following were added: puffed wheat, defatted wheat germ, soy nuggets, soy protein, and soy fibre into a 5-quart Kitchen Aid mixing bowl (the mixer was fitted with a flat beater attachment). Ingredients were blended on the lowest setting for 1 min and set aside. The 3-quart metal pan was placed on a large stove burner, which was then turned to high. The mixture was stirred and the side

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>WB (g kg⁻¹)</th>
<th>WBC (g kg⁻¹)</th>
<th>SBC (g kg⁻¹)</th>
<th>WSBC (g kg⁻¹)</th>
<th>WB3% (g kg⁻¹)</th>
<th>WB6% (g kg⁻¹)</th>
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<td>–</td>
<td>1.97</td>
<td>56.2</td>
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<td>113.5</td>
<td>3.29</td>
<td>94.0</td>
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<td>6.50</td>
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<td>181.9</td>
<td>5.26</td>
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<tr>
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<td>–</td>
<td>7.08</td>
<td>202.3</td>
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<td>Soy nuggets¹⁰</td>
<td>–</td>
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</tbody>
</table>

¹ Stage 1 ingredients.
² Stage 2 ingredients.

Different treatments: WB, wheat bar; WBC, wheat bar with coating; WSBC, wheat and soy bar with coating; SBC, soy bar with coating; WB3%, wheat bar with 3% glycerin; WB6%, wheat bar with 6% glycerin.

The following materials were generously donated by their respective companies: Arise 8000 from MGP Ingredients (Atchison, KS, USA), gum arabic from TIC Gums (Belcamp, MD, USA), Panodon 150K from Danisco (New Century, KS, USA), Pearl White Confectionery Coating from ADM Cocoa (Milwaukee, WI, USA), Red #40 Lake from Sensient (St Louis, MO, USA), strawberry flavour from Danisco (New Century, KS, USA), soy fibre, soy nuggets, and soy protein from The Solae Company (St Louis, MO, USA), and wheat germ from Viobin USA (Monticello, IL, USA).
walls were scraped as the ingredients heated. The temperature was checked with a calibrated digital thermometer and heating continued until the ingredient mixture reached 85 °C, which took approximately 4 min. The pan was removed from the heat and the Stage 1 ingredients were poured over the Stage 2 ingredients and mixed for approximately 45 s. The blended mixture was then poured into a 33 cm × 23 cm × 1.5 cm metal pan that was lined with parchment paper. Using a wooden rolling pin, the mixture was then pressed into a block 10 cm × 1.5 cm in size. The block was allowed to cool for 20 min at room temperature from the time the Stage 1 and Stage 2 ingredients were mixed together. The block was then cut with a knife (using five cuts) to produce six equal-sized bars. Cuts were made between the third and fourth bar first, between the second and third bar second, between the fourth and fifth bar third, between the first and second bar fourth, and between the fifth and sixth bar last.

After cutting, the coating was mixed and applied to some of the bars. The Pearl White Confectionery Coating was placed in a glass beaker and heated at half power (750 W) in the microwave until soft and creamy, about 90–120 s. The red lake and flavouring were then added to some of the coating and it was mixed with a stirring rod until well blended, approximately 2 min. The coating was then spread over bars 2, 3, 4 and 5 and allowed to dry for 30 min at room temperature. The bars were then well wrapped with clear polyethylene cling wrap and held for 24 h before being tested, the results of which are shown in Fig. 1.

The uncoated samples were allowed to cool an additional 5 min from the time the bars were cut and were then well wrapped with clear polyethylene cling wrap. The samples were held at room temperature for 24 h before testing.

**Physical and chemical measurements**

**Water activity**

An Aqua Lab water activity meter (Decagon CX-2; Decagon Devices Inc., Pullman, WA, USA) was used after being calibrated with standard salt. Bar samples were crumbled into small pieces and loosely placed into the plastic sample cups until the cups were approximately half full. The cups with the bar samples were then placed into the measuring chamber one at a time.

**Colour**

Colour was measured using a Hunter MiniScan portable colourimeter (HunterLab, Reston, VA, USA). The colorimeter was calibrated using a light trap and a white tile according to the procedure given in the owner’s manual provided by HunterLab. Colour was measured using natural light (C) at a 10° angle. Three measurements of each sample were taken and then averaged. The L, a, and b values were all recorded. These bar colour attributes can be defined as the following: L refers to lightness; a refers to redness to greenness; and b refers to yellowness to blueness. Procedures for colour were adapted from Lee et al.

**pH measurements**

The pH of the bars was measured with a pH meter (Accumet portable AP63; Fisher Scientific, Denver, CO, USA) with automatic temperature compensation, the electrometric method, AACC method 02–052. The pH meter was calibrated with buffer solutions at pH 4.0 and 7.0 All measurements were recorded at ambient temperature when the readings were stable.

**Moisture content**

The moisture content of the bars was measured using AACC method 44-15A. Approximately 7 g of sample were placed in an aluminum pan (Fisher Scientific, Pittsburgh, PA, USA) and heated at 104 °C for at least 24 h.

**Texture analysis**

A frequently used type of texture measurement is the texture profile analysis (TPA). The TPA imitates the mouth and palate, and can quantify texture characteristics of hardness, cohesiveness and springiness. The TPA is a technique using a two-cycle compression test, which imitates two bites. Texture was determined with TA-XT2 Texture Analyzer (Texture Technologies Scarsdale, NY, USA) according to the AIB standard procedure for cake. The texture analysis was conducted using a TA.XT2 Texture Analyzer 5-kg model (Stable Micro System Ltd., Scarsdale, NY, USA), along with the texture analysis program. This combination was used for measuring and recording sheer force. A knife blade of 57 mm in length was used and each bar was tested in four locations. The first measurement was made one inch from the end of the bar that was not touching the pan when formed. The second measurement was two inches from the same end, the third measurement was three inches from the same end, and the fourth and final measurement was taken four inches from the same end. The blade was aligned perpendicular to the bars so that with each impression, the bar was tested completely from side to side. The blade was lowered to within 3 mm of the platform, thus not completely severing the product. By leaving the last 3 mm, false data (which would have been produced by compacting the product) was avoided. Based on preliminary work, the instrument parameters were set with a pre-test speed of 2.0 mm s⁻¹, a post-speed of 10.0 mm s⁻¹, a distance of 25.0 mm, and a data acquisition rate of 200.00 pps. Texture analysis is an empirical technique, which uses a universal testing machine that compiles readings of force during compression and over time. Data analyses correlate numerous sensory parameters.

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**Figure 1.** Processing steps used in the preparation of wheat and soy nutrition bars.
including hardness, cohesiveness, and springiness, with texture terms determined from the texture profile analysis curve. In the study of the nutritional bars, only hardness was analysed in relation to the amount of force needed to bite through a food bar.

Microbiological analysis
The bar samples were evaluated for microbiological quality. Samples of the Stage 2 ingredients were tested as well as the final product. Stage 2 ingredients were chosen for testing because this stage was not heated directly. The analysis was performed on the samples immediately after production to confirm that this stage was not heated directly. The analysis was performed final product. Stage 2 ingredients were chosen for testing because Samples of the Stage 2 ingredients were tested as well as the The bar samples were evaluated for microbiological quality. Samples of the Stage 2 ingredients were tested as well as the final product. Stage 2 ingredients were chosen for testing because this stage was not heated directly. The analysis was performed on the samples immediately after production to confirm that the method of processing was adequate in reducing microbial population. Samples (10 g) were taken from each variety of bar and diluted in 90 g of sterile diluent (Weber Scientific, Hamilton, NJ, USA). Microbiological tests were performed using 3M Petrifilm™ Plates (3M Microbiology Products, St Paul, MN, USA) for yeast and mould count, total aerobic plate count, and E. coli/coliiforms. The aerobic and E. coli/coliiform plates were held in an incubator (Boekel Industries Inc, Feasterville, PA, USA) at 35 °C and the yeast and mould plates were held at 20 °C for 48 h before evaluation.

Sensory evaluation
A total of 118 untrained panelists participated in the sensory evaluation of the nutritional bars. These panelists consisted of 50 men and 68 women between the ages of 18 and 70. Panelists were pre-screened for potential food allergies and on the basis of having consumed nutritional bars. Approximately 47% of the panelists had at least some college education and 39% consume food bars at least once a week. Prior to beginning the sensory study, all panelists signed an informed consent statement.

The sensory evaluation was conducted at Kansas State University in the Food Science Laboratory at Call Hall. All six of the products developed were evaluated in this study. Bar samples were presented on odourless white plastic plates at ambient temperature with three-digit random number codes. All samples were presented at one time and the sampling order was predetermined by the order listed on the evaluation sheets. By controlling the sampling order in a random manner, bias was eliminated. Unsalted crackers and distilled water were provided for cleansing between samples. Panelists were instructed to use the crackers and water to cleanse their palates before tasting the samples and at any time during the test as needed. Evaluation was conducted using a nine-point hedonic scale to determine the degree of liking for bar products (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely). The samples were rated for overall acceptability, appearance, flavour, sweetness and texture. Analysis of variance (ANOVA) was used to determine statistical significant difference between samples.

Nutrition labelling
The nutritive composition of the final wheat and soy bars (carbohydrate, fat, protein, fibre, calories, also minerals such as Na, K, Ca, Mg, Fe, Zn, P, and vitamins such as A, D, E, K, thiamin, riboflavin, niacin, pantothenic acid, folic acid and biotin) were determined using the Genesis R&D labelling program (ESHA Research, Salem, OR, USA). The serving size was determined as stated in the FDA 21 CFR 101.9 (b) guideline. The serving size used for nutrition labelling was for bars meant to compete in stores. Alterations were made to the serving size in order to make the bar size adequate for food aid. In a food aid situation, nutritional content is very important, along with ease of transport and distribution. For these reasons, the food aid-sized bars were larger. All ingredients for every bar were entered into the Genesis program and the moisture content adjusted to reflect the values obtained by the oven method. Final nutritional analysis statements were used to determine allowable claims for the products.

Statistical design
Six varieties of bars were evaluated and compared to one another. Three replications were treated as blocks in a randomised block design. Except for sensory analysis, triplicate readings for each physical and chemical test were performed. All physical, chemical, textural, and sensory data were analysed using SAS Statistical Software. The analysis of variance (ANOVA) and least significant difference (LSD) were used to determine the significance of main effects at P < 0.05 among treatments.

RESULTS AND DISCUSSION
Water activity
Table 2 shows the chemical and physical properties for six varieties of nutrition bars at day 1. It was found that WB and WBC had the highest water activities, 0.688 and 0.682 respectively, among the varieties, but were not significantly (P > 0.05) different. WSBC had the lowest mean water activity of 0.51. This difference is likely due to the fact that WB and WBC have 9.18% and 7.8% water added respectively, where WSBC does not have any added water.
water activity levels are below 0.70 and are expected to be stable against microbial growth and have a shelf life of approximately 6 months.

Even though the bar samples had a water activity below the required level for yeast, moulds, and bacterial growth, the levels measured are similar to the water activities of a soft, chewy type of product. The water activity for some nutritional bars is as low as 0.1–0.5.17 Bars with this low value for water activity will be ‘crunchy’ in texture.17 The type of bar produced for this experiment had a softer, chewier texture. The researchers believe that a softer bar would be favourable in some under-developed societies that may not have advanced dental care.

The water activity of the coating alone was 0.46. This is lower than the water activity of any of the bars. The coating will assist in extending the shelf life of the bars. This coating is a protective barrier that will keep air (along with microorganisms) from contaminating the bars. The bars cannot absorb moisture from the surrounding environment because this coating will seal the surface from such interactions.

According to Labuza,19 water activity has a profound effect on the rate of many chemical reactions in foods and on the rate of microbial growth.19 Moulds and yeasts will start to grow at a water activity between 0.7 and 0.8. Bacterial growth will take place when water activity reaches 0.8.20 It was important to control the water activity in the food bars to avoid these types of growth.

Colour

The $L$ values for WSBC, SBC and WBC were not significantly different ($P > 0.05$). This was expected because the three samples had same white confectionary coating. Samples WB, WB3% and WB6% were not statistically different from one another ($P < 0.05$), but were significantly different from the three coated treatments ($P < 0.05$). The three bars with coating had higher $L$ values, which indicated that they were lighter in colour and the three non-coated bars had lower $L$ values, and therefore were darker in colour.

The $a$ value for colour represents the red–green axis. WB, WB3% and WB6% had the positive $a$ value and were therefore slightly red. WSBC, WBC and SBC had negative $a$ values and leaned toward the green colour. All values were close to zero and therefore were not highly red or green.

The $b$ values measure the blue–yellow values. All variables were positive, and therefore were slightly yellow. The coated samples had lower values, and thus were not as highly yellow-coloured as the uncoated samples.

Former research has concluded that the colour of whole grain samples had the following ranges: $L = 40.9–50.4$, $a = 7.0–8.3$ and $b = 13.6–19.1$.21 These values are very similar to the values that were obtained for the three varieties of bars containing puffed wheat that were not coated, WB, WB3% and WB6%. It is likely that the wheat was the primary determinant of the colour.

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### Figure 2. Nutrition label for the wheat bar, WB.

### Figure 3. Nutrition label for the wheat bar with coating, WBC.
When evaluating colour, several variables should be considered and standardised.\textsuperscript{20}

**pH measurements**

All mean pH measurements fell between 5.11 and 6.45 (Table 2). Snack bars containing soy flour had higher pH values than those containing wheat flour. Soybeans typically have pH values ranging from 6.0 to 6.6.\textsuperscript{22} Unbleached bread flour has a pH value range of 5.8–6.0. These pH values explain the primary differences between the pH values of the bars because soy and wheat were the major components of the bars, as well as the primary difference between the bar samples.

**Moisture content**

The moisture contents of the nutrition bars differ significantly ($P < 0.05$), Table 2. These differences are primarily due to the degree of water added to the system as well as to the varied ingredients and the moisture content that was introduced. Moisture values ranged from 20.68 for WBC and 10.10% for WSBC, respectively. WB had the second highest moisture content at 16.59. WBC had 7.80% water added directly into the formula. WB had 9.18% water addition. These high values of water in the formula explain why these two varieties had the highest moisture contents. WSBC, which had the lowest moisture content, did not have any water added to the formula.

**Texture analysis**

For the study of the nutritional bars, only hardness was analysed and was thought to correspond to the amount of force needed to bite through a food bar. The hardness analysis results (force) showed that all varieties of bars were statistically different ($P < 0.05$) when evaluating force (Table 2). Hardness (force) was affected significantly by changing the components of all formulations. There were large differences between samples and within the varieties as well. This was expected because the bars contained particulates that were of varying size and shape. In addition, the bars were made by hand in a laboratory, which caused additional variation to the hardness. This variation can be solved by using specific equipment which could evenly coat the bars; all bars would then be coated with the same thickness of coating. WBC had the lowest value for hardness. This was not expected because the coating does give a firm shell, but this bar did have a very tender interior and a rather thin layer of coating. The WSBC had the highest values for hardness, which was expected due to the thick coatings applied to these bars.

Consumers often favour a bar that ‘has a soft texture while retaining the crunchiness of cereal’.\textsuperscript{18} A similar texture was
achieved with SBC. The wheat-based bars were not as crunchy in texture, but softer and chewier.

**Microbiological analysis**
The dry blends showed low levels of yeasts and moulds with a mean of 3 colony-forming units, but the heat of processing eliminated these units from the final product. The heat given to the first stage of ingredients reduced any microorganism counts found in these ingredients in the yeast and mould plate counts, aerobic plate counts, and \textit{E. coli} and \textit{coliforms} plate counts. Heat eliminated microorganisms in the dry blend as well once the dry ingredients were brought to a temperature of 185°C (upon being blended with the hot Stage 1 ingredients prior to formation of the bars). The production method used was sufficient for producing a product that had an acceptable bacterial quality.

**Sensory evaluation**
Mean values for overall acceptability, appearance, flavour, sweetness and texture are given in Table 3. SBC received the highest scores for overall acceptability, appearance, sweetness, flavour and texture. WSCB received the second highest score in all categories. From these results, it appears that consumers prefer the soy varieties to the wheat bars. The higher levels of glycerin consistently received the lowest scores. It appears that glycerin should not be used at such high levels, i.e. 3% and 6%, in food bars.

![Figure 6. Nutrition label for the wheat bar with 3% glycerin, WB3%](image)

**Nutrition Facts**

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**Protein**

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*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.*

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</thead>
<tbody>
<tr>
<td>Total Fat</td>
<td>Less than 65g</td>
<td>80g</td>
<td></td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>Less than 20g</td>
<td>25g</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>Less than 300mg</td>
<td>300mg</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>Less than 2,400mg</td>
<td>2,400mg</td>
<td></td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>30g</td>
<td>375g</td>
<td></td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>25g</td>
<td>50g</td>
<td></td>
</tr>
</tbody>
</table>

**Nutrition labelling**
The nutritive composition of the wheat–soy snack bars are presented in Figs 2 to 7. These bars can be considered as good sources of high quality proteins, fibres and B-complex vitamins as can be seen in the nutrition facts labels. This variation in the composition of the bars gives the consumer the ability to select the suitable bar to purchase. These types of bars can aid in

![Figure 7. Nutrition label for the wheat bar with 6% glycerin, WB6%](image)
feeding starving populations and give relief when natural disasters occur. Athletes and outdoorsmen will enjoy the convenience and portability of such a food along with the general population that is becoming increasingly concerned with nutrition and convenience.

CONCLUSIONS

No-bake nutritional bars were produced from wheat and/or soy products that can provide nourishment to consumers with a satisfactory sensory, physical, microbial and chemical attributes. Preliminary research was conducted to evaluate the shelf-life of the bars. Zip-lock bags were used for packaging and it was determined that this type of package did not give representative values. Additional testing will be conducted during the next phase with proper packaging materials.

REFERENCES