Formulation and experimental production of energy bar and evaluating its shelf-life and qualitative properties

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Abstract

Aims: Energy bars can improve armed forces’ performance during military missions, especially if there would not be enough time for food consumption. The aim of this study was formulating and experimental production of energy bars for emergency conditions such as patrol, cold weather and heights.

Methods: After formulation and experimental production of 10 energy bar samples, the optimum formulation was selected by taste panels. Shelf life and also qualitative (organoleptic, chemical and microbial) properties of the selected formulation were evaluated 0, 3 and 6 months after production at 38°C (equal to 0, 18 and 36 months at 27°C).

Results: Although organoleptic properties and moisture content of the samples were decreased negligibly after 6 months of incubation at 38°C, there was no significant difference (p<0.05) with those produced at the beginning of the experiment. Even 6 months after incubation at 38°C, microbial properties and peroxide value of the samples were in the standard range.

Conclusion: Shelf life and also qualitative properties of the produced energy bar are acceptable after 6 months of incubation at 38°C (equal to 36 months of incubation at 27°C) and this energy bar can be easily used in emergency conditions.

Keywords: Energy Bar, Formulation, Shelf Life, Qualitative Properties

Introduction

The increase of soldiers’ efficiency in military operations requires suitable nutrition. Since military forces are able to fulfill the assigned operations, they should reach enough water and food as well. Soldiers with adequate nutrition are able to tolerate the hard environmental situation of the battlefield much better. Otherwise, the possibility of performing a victorious battle is doubtful due to physical weakness. The base for nutrition in battlefields is military energy bars. The energy bar includes supplying the one-day food for one individual. The type of soldiers’ energy bars is determined based on the mission of the operational units, war tactics, situation, and access to the personnel and food serving equipment [1, 2, 3, 4, 5, 6]. In classic wars and military maneuvers two types of energy bars are considered for feeding the fighting forces. The first bar is the “operational bar” that is especially for the first 24 hours of the operation in classic wars. The second type of these bars, is the “emergency bars” that is related to the time, at which the food has not been transferred to the marital operating forces by the supporting forces. The emergency bar should have the least weight and volume enough for one individual’s vital activities. Some types of toffee and semi-solid chocolates with different smells, flavors and compositions are usually used in order to make the emergency bars. These bars can be used as “survival bar” as well [7, 8]. To meet the special needs, designers design bars of army forces and supply their prototypes. Energy bars can improve the individual’s efficiency in war operations (especially if there’s not enough chance for using foods). According to the army forces’ recommendations the food bars are repeatedly updated. In most of the cases, the food producers produce these food supplies similar to the commercial food and the army forces’ bars are only packed in special packages [3, 7, 9]. Food packaging for army forces makes the shelf-life longer (at least 3 years at 27°C or 6 months at 38°C for the individual operation food bars). Moreover, in order to make the shipping much easier, the food packages are much pressed and get much lighter. The most commonly used packaging for war food bars are flexible packages. Aluminum foil is resistant against light, humidity, gas, and microorganism penetration, the products shelf lives. The internal and external layers are made from polypropylene that’s compatible with humidity and acidic foods, and provide suitable lid coverage, flexibility, high quality of packaging and smell and flavor stability for types of food products. The lasting period of these products in these packages are at least equal to cans. However, they occupy much smaller space and are lighter; moreover, they can be
easily opened by tearing off [10, 11, 12, 13]. In Iran, different kinds of bars are experimentally produced; however, no bar has been used as the emergency bar yet. The aim of this research was formulating and experimental test of energy bar in a way that can be used in emergency conditions (such as patrolling and in cold weather) [14, 15, 16, 17].

Table 1- Ratio and percentage of combinations in primary energy bar samples formulation

<table>
<thead>
<tr>
<th>Row</th>
<th>Combination name</th>
<th>Combination ratio</th>
<th>Combination percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sugar</td>
<td>1</td>
<td>16.66</td>
</tr>
<tr>
<td>2</td>
<td>Glucose syrup</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>3</td>
<td>Honey</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>4</td>
<td>Sesame pudding</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Sesame paste</td>
<td>1</td>
<td>16.66</td>
</tr>
<tr>
<td>6</td>
<td>Shortening</td>
<td>1</td>
<td>16.66</td>
</tr>
<tr>
<td>7</td>
<td>Albumin powder</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>8</td>
<td>Low-fat powdered milk</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>9</td>
<td>Nonfat powdered milk</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>10</td>
<td>Coconut powder</td>
<td>0.925</td>
<td>15.45</td>
</tr>
<tr>
<td>11</td>
<td>Cacao</td>
<td>0.0625</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Vanilla essence</td>
<td>0.00625</td>
<td>0.1</td>
</tr>
<tr>
<td>13</td>
<td>Lecithin</td>
<td>0.00625</td>
<td>0.1</td>
</tr>
<tr>
<td>14</td>
<td>BHT</td>
<td>0.000625</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 2- Scoring and formulation of the first samples of energy bar

<table>
<thead>
<tr>
<th>Formulation number</th>
<th>Formulation</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glucose syrup, Sesame paste, Albumin powder</td>
<td>11.50</td>
</tr>
<tr>
<td>2</td>
<td>Glucose syrup, Shortening, albumin powder</td>
<td>13.45</td>
</tr>
<tr>
<td>3</td>
<td>Sesame powder, Low-fat powdered milk</td>
<td>14.25</td>
</tr>
<tr>
<td>4</td>
<td>Glucose syrup, Sesame paste, Low-fat dry powdered milk</td>
<td>12.20</td>
</tr>
<tr>
<td>5</td>
<td>Glucose syrup, Shortening, Low-fat powdered milk</td>
<td>14.05</td>
</tr>
<tr>
<td>6</td>
<td>Sugar, Sesame paste, Low-fat powdered milk</td>
<td>12.80</td>
</tr>
<tr>
<td>7</td>
<td>Sugar, Shortening, Low-fat powdered milk</td>
<td>13.20</td>
</tr>
<tr>
<td>8</td>
<td>Honey, Sesame paste, Low-fat powdered milk</td>
<td>14.20</td>
</tr>
<tr>
<td>9</td>
<td>Honey, Shortening, Low-fat powdered milk</td>
<td>15.70</td>
</tr>
<tr>
<td>10</td>
<td>Honey, Shortening, Non-fat powdered milk</td>
<td>14.65</td>
</tr>
</tbody>
</table>

Coconut powder, cacao, vanilla essence, lecithin, and BHT were used equally and with the same amount in all samples.

Methods

Providing different types of army bars: All the fundamental components of energy bars were provided from Azerbaijan Confectionary Materials & Equipment Distribution Center. After collecting necessary information and providing ingredients and equipment, 10 test samples were produced by different formulations. In these formulations, carbohydrate, protein, and fat resources were used. Glucose syrup, honey and sugar were used as carbohydrate source, Sesame paste and shortening were used as fat source and albumen powder, low-fat powdered milk and nonfat powdered milk were used as protein source. In all samples coconut powder, cacao (for creating color, and taste), vanilla essence (as flavors), lecithin (emulsifier) and Butylated Hydroxy Toluene (BHT) Antioxidant were used equally. The ratio of compositions in the formulations of the first types of energy bars are shown in Table 1. In order to choose the optimum formulation, 20 types were used for the primary organoleptic analysis from each formulated type. The formulation of the primary energy bar samples are shown in Table 2.

According to Tables 1 and 2, the ingredients were weighed at the outset. Then, the oil source (shortening or sesame paste) were mixed with protein source (low-fat powdered milk, non-fat powdered milk or albumin powder) in food processor Moulinex (model DFC6; France) for 5 minutes at 300rpm. Then, the rest of compounds (coconut powder, cacao powder, vanilla essence, lecithin and BHT) were added gradually, mixed and homogenized for five more minutes at 180 rpm. The viscosity of mixture increased by adding by adding the compounds and lower speeds were used afterwards and then the carbohydrate source (glucose syrup or honey) was added that increased the viscosity. At the last stage, in order to complete the process, mixing continued for more five minutes at 60 rpm. The obtained mixture was brought out of the food processor and the mixture was molded in 1×4×8 centimeters 60-gram bars by manual molder.

The organoleptic analysis of prepared samples: In this project, adaptive classification method was used using the relative scale. Since this formulation was stated as an army bar, 20 specialist raters were used for organoleptic assessment. Before assessment, a detailed explanation was presented about the type of assessments to the assessors. A special code was assigned to each sample. Then the samples were handed to the assessors to be rated based on the general specifications from 0 to 20 (0 for the worst quality and 20 for the best quality) [18, 19, 20, 21].

Selection and organoleptic evaluation of the optimal formulation: Among the mentioned formulations, formula number 5 was used as the optimal formula. Then this formulation was assessed by assessors regarding flavor, smell, color, texture uniformity, softness, lack of adhesion to tooth and desirable appearance from 0 to 20 (0 for the worst and 20 for the best quality).

Packaging and maintenance of samples: According to the selected formulation (formulation number 5), 75
60-gram samples were packaged in Nitrogen gas controlled atmosphere. The packaging material was an aluminum foil (Zarnab Golestan; Iran) that was covered with low density polyethylene on both sides. The packaging machine was bought from Tehran pack Package Industry (Model 40 MTQ; South Korea). Then the packed samples were kept for a 3 and 6-month period at 38°C for organoleptic, chemical and microbial analysis (respectively equal to 18 and 36 months at 27°C) [10].

**Sample volume:** 75 samples were considered for organoleptic, chemical and maintenance in 0, 3 and 6 months intervals at 38°C out of the required samples after formulation and sample selection (25 of the selected formulation for each level of laboratory and durability tests).

**Final tests on the optimized sample:** All the chemical and microbial culture environment were bought from Merk Co.; Germany. Chemical tests included humidity, fat, protein, ash, and carbohydrate evaluations [22, 23, 24, 25, 26]. Microbial and peroxide index tests were done to determine the level of durability [27, 28, 29, 30]. Packed bars and the package quality (preferably its impenetrability to humidity and microbial factors) were analyzed and studied by multi-layer aluminum packaging. Organoleptic tests were done to determine the quality and desirability of the produced bar. The energy bar characteristics were matched with the national standard regarding military and other properties.

**Analysis method:** Panels analyzed the samples using questionnaires including preferential and exponential tests. Data analysis was performed by SAS software version 9.1 and based on GLM method by mean comparison LSD test in 95% confidence interval (p<0.05). The related diagrams were drawn by Microsoft Office Excel 2007 version 14.

**Results**

**The utilized sample for producing energy bar:** Samples ratings were in the range of 11.50 to 15.70 out of total 20 scores (Table 2). Samples 9, 10, 3, 8, and 5 were 5 superior samples regarding the quality properties respectively and no significant difference was observed among them. Among these samples, sample number 5 was selected as the desirable sample. This sample has glucose syrup as carbohydrate source, and shortening as the fat source and low-fat powdered milk as the protein source. The components of this sample and the ratios are fully shown in Table 3.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test description</th>
<th>Total numbering</th>
<th>Salmonella</th>
<th>Enterobacteriaceae</th>
<th>Excherichia coli</th>
<th>Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample the beginning of production</td>
<td>4.4×10²</td>
<td>In 25 grams sample, negative</td>
<td>Less than10</td>
<td>Negative</td>
<td>Less than10</td>
<td></td>
</tr>
<tr>
<td>Packed sample with Nitrogen gas</td>
<td>Three months after production</td>
<td>8.010²</td>
<td>In 25 grams sample, negative</td>
<td>Less than10</td>
<td>Negative</td>
<td>Less than10</td>
</tr>
<tr>
<td></td>
<td>Six months after production</td>
<td>1.0×10³</td>
<td>In 25 grams sample, negative</td>
<td>Less than10</td>
<td>Negative</td>
<td>5.0×10⁴</td>
</tr>
<tr>
<td>Standard limit</td>
<td>-</td>
<td>In 25 grams sample, negative</td>
<td>10⁴</td>
<td>Negative</td>
<td>10⁴</td>
<td></td>
</tr>
</tbody>
</table>

*Based on Iranian national standard, number 2395 Sweets and confectionary-microbiological specifications [28]*

**Energy calculation in the selected sample:** This sample included 56.26% carbohydrate (total sugar), 24.28% fat, and 8.98% protein. Regarding the fact that 4, 9, 4 kilocalories releases from the metabolism of each gram of carbohydrate, fat, and protein respectively, 100 grams of this formulation produces 480 kilocalories and the share of carbohydrate, fat, and protein is 225, 219, and 36 kilocalories respectively.

**Organoleptic analysis of the produced energy bar at different time intervals:** Organoleptic analysis of the selected sample is shown in Diagram 1 on the basis of 7 factors of smell, taste, color, texture uniformity, softness, non-adherence and desirable appearance at the beginning of production and after 3 and 6 months. The scores of organoleptic indexes decreased after 6 months; however, no significant difference was observed in the beginning of production and 3, and 6 months after production.

**Microbial tests of the produced energy bar at different time intervals:** Conducted microbial tests
included the total number of microorganisms, salmonella, Enterobacteriaceae, Escherichia coli and mold. Although the total number of microorganisms increased from $4.4 \times 10^2$ to $1.0 \times 10^3$ colonies/gram through passing time from 0 to 6 months after production, the total number of microorganisms was still in standard limit after 6 months. The achieved results about microorganisms, Salmonella, Enterobacteriaceae and Escherichia coli was statistically equal and in the standard limit for the samples in the beginning of production and in 3 or 6 months after that at $38^\circ$C. There was equal number of mold in the beginning of production and after 3 months (<10 colonies/gram); however, in those samples packed with nitrogen gas of which 6 months passed, the number of mold had increased ($5.0 \times 10^1$ colonies/gram).

Of course, the number of counted molds was in a standard limit in all cases (<10$^2$ colonies/gram) (Table 4).

Through passing time, the amount of extracted fat peroxide index increased; however, this increase was in standard limit even 6 months after production (Table 6).

**Discussion**

**Optimal sample for production of the energy bar:** Samples 9, 10, 3, 8 and 5 were respectively 5 superior samples regarding quality. Based on the conducted analysis, sample 5 was chosen as the optimal sample.
Formula number 3 and sample number 8 were omitted due to improper texture and fat oil leakage. Samples 8, 9 and 10 were expensive due to containing honey in formulation and were not producible in necessary conditions at higher volumes. However, sample 5 was considered as the optimal formulation since it had suitable texture and color and its whole components were available easily and at higher amounts in Iran. Sample 5 formula composed of glucose syrup, shortening, low-fat powdered milk, coconut powder, vanilla essence, lecithin and Butylated Hydroxy Toluene. All the components used in the selected sample are inexpensive and almost all of them are produced in Iran in industrial scale and thereupon, are producible and disposable easily and in industrial scale in crisis condition (war or sanctions). Moreover, since this sample doesn’t need to be heated and is only prepared by mixing or molding, it is easily producible. In this formulation, low-fat powdered milk and shortening are used as protein and fat sources, respectively. These components have very low aqua activity; thereupon, the available water for microorganisms is limited. Even glucose syrup and coconut powder have high shelf-lives. Besides these specifications, Glucose syrup produces energy for the warrior immediately after use and even hours after use, due to having simple sugar and oligosaccharides. Since no heat is applied while production, vanilla essence is used that is flavor giving, antioxidant and antimicrobial with long-term maintenance instead of vanilla that may cause microbial contamination. Various studies have verified antimicrobial, antifungal, anti-mutant and antioxidant characteristics of oleoresin vanilla essence [31]. In this formulation Butylated Hydroxy Toluene antioxidant was used in standard amount, because fat bitterness is one of the most important decay types in products with high shelf lives [23, 26, 27, 32].

“Hooah” is the last and the most important brand of energy bar in the U.S. Defense Ministry, which is offered to the markets for general use as well. Hooah has also been used in Iraq and Afghanistan. This bar contains corn syrup as the carbohydrate source, palm oil as the fat source and soya protein [33].

**Calculated energy in the selected sample:** Various studies have analyzed the level of energy required for army forces [16]. The sample produced includes 56.26% carbohydrate (total sugar), 24.28% fat and 8.98% protein. 100 grams energy bar produced, produce 480 kilocalories. Normally, energy bars produced in army bars of other countries own 400-500 Kcal energy in 100 grams. These bars normally include 60 grams of carbohydrate, 15 grams of fat and 12 grams of protein [16, 17]. In a similar research Farajzadeh designed an emergency bar based on date juice that included 65% carbohydrate, 17% fat and 2% protein. Each 100 grams of this bar produces 497 kilocalories that is similar to the energy of 100 grams of energy bar produced in this research [34].

**Organoleptic analysis of the produced energy bar at different time intervals:** Based on the results of organoleptic analysis, there was no significant difference among different samples at the beginning of production process and 3 and 6 months later at 38°C (equal to 0, 18 and 36 months at 27°C) [18, 19, 20, 21]. In Farajzadeh’s bar formulation in 1999, the results of organoleptic analysis and the rate of satisfaction regarding specifications such as flavor, smell, color, softness, non-adherence, package quality and desirable appearance have been respectively 16, 13.2, 14.8, 18.8, 18.8, 13.2 and 14.8. This amount of desirability is similar to the results achieved from organoleptic analysis in the present study [34].

**Microbial testing of the produced Energy bar at different time intervals:** Microbial tests included the total number of microorganisms, *Salmonella, Enterobacteriaceae* and *Escherichia coli*. By passing of time from 0 to 6 months after production, although the total count of microorganisms and mold increased slightly, the count of *Salmonella, Enterobacteriaceae* and *Escherichia coli* did not change and remained in the determined standard limit [23, 26, 28, 29, 30]. Applying suitable components, using essence and good method of production are factors that prevent microbial growth in the produced energy bar. Low-fat powdered milk, shortening, glucose syrup and coconut powder are used in this formulation. These compounds have very low aqua activity; thereupon, the available water for microorganisms is limited. Vanilla essence has antimicrobial activity as well as giving flavor. Moreover, robustness of packages used in comparison with microorganisms and humidity is another preventive factor. In Farajzadeh’s study in 1999, microbial specifications of bar produced has been in standard range as well [34].

**Chemical testing of the produced energy bar at different time intervals:** The level of humidity in samples decreased slightly through passing of time. This reduction can be one of the main reasons for reduction of desirability and the score of some organoleptic specifications such as its softness rate. Thereupon, multilayer package using aluminum foil and low density polyethylene is a suitable method for keeping the humidity of sample (even 6 months after production at 38°C) [10]. Regarding other components such as total sugar, fat, protein and ash, no significant
difference was seen among samples at different time intervals (0 to 6 months).

Although peroxide the extracted fat index increased by time even 6 months after production, this increase was in the standard range 923, 26, 27]. Using antioxidant compounds, vanilla essence and good production methods are among the reasons that peroxide index stays low after 6 months. Vanilla essence prevents excessive increase of energy bar peroxide fat index in addition to flavor giving and anti-microbial specifications. By the way, impermeability of the package to light and oxygen is another effective factor in holding down the peroxide index [33]. Many studies have considered the use of new methods of packaging such as changed atmosphere, controlled atmosphere and active packaging, and using absorbents are effective in decreasing the peroxide index [11, 12, 33]. Farajzadeh reported the peroxide index of his produced bar as 2.1 m Eq. gram/kg after 10 months at 30°C that was higher than the standard rate and was almost two times more than the peroxide index of the bar produced in present research after 6 months of keeping at 38°C. It seems that using natural antioxidants (vanillin) and synthetic ones (BHT) in formulation of the bar produced in this research was the main reason that the peroxide index remained low [34].

Conclusion

Main reasons of choosing the mentioned energy bar are specifications such as texture and suitable color, easy production, no need for heating during production and the availability of all the components. This bar had no significant difference after 6 months of incubation at 38°C considering organoleptic, microbial and chemical aspects and the peroxide index in comparison with the samples produced at the 0 interval. Even after 6 months of incubation at 38°C, all the qualitative and even bar shelf-life are in standard and acceptable range. These results show that this bar can be used in emergency condition as an energy bar.

References

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