ABSTRACT

An n-order mathematic expression was used to evaluate the shelf-life quality and deterioration of a newly developed power bar for immune-deficient patients. Accelerated shelf-life testing conducted at 40, 50 and 60°C was used to predict the shelf-life of the product at usual storage conditions. The Arrhenius model that was used indicated that the power bar can be stored for 168 days at 4 ± 1°C, 105 days at 9 ± 3°C, 56 days at 15 ± 5°C, 21 days at 30 ± 2°C, and only 6 days at 42 ± 3°C. The calculated Q10 values were found to be in the range of 1.5-2.0, which is in the range for lipid oxidation in various food products reported in the literature.

Keywords: food, HIV, n-hexanal, quality, storage, use by date

INTRODUCTION

Inadequate food intake is the first significant cause of death in case of Human Immune Virus (HIV)/Acquired Immuno-Deficiency Syndrome (AIDS) affected peoples (World Health Organization 2003; Zello 2006). Nutritional and micronutrient deficiencies play an important additive role in immune degradation (Anabwani and Navario 2005). In the case of peoples living with HIV/AIDS, there is a need to boost their immune systems by means of nutrition (WHO 2003), specifically in the case of highly active anti-retroviral therapy (Hogg et al. 1999). Research on boosting the immune system of peoples living with HIV/AIDS by means of nutrition has been reported and mainly focused on the production process of energy bars, food multimixes, and porridges for immune-deficient patients (Meyers et al. 1995; Cassano and Drioli 2004). In order to contribute to solve this problem, a power bar, for immune-deficient children was developed at the Vaal University of Technology. This is a powerful immune-enhancing meal formula, combining a comprehensive blend of nutrients in a pleasant-tasting, pre-cooked, ready-to-use, nutritious and ethnically acceptable food. In theory it is acceptable to mix ingredients from different sources (carbohydrates, proteins, lipids) and fortify these by adding vitamins and some essential minerals (selenium, iron, zinc, calcium) to meet energy, protein and micronutrients needs (Amuna et al. 2004; Cassano et al. 2004). The effects of time and storage conditions in the nutrient contents and shelf-life of this power bar, however, are not yet well understood. As the storage and environmental conditions may affect its nutritious quality, the determination of the shelf-life of this new food product is required. The research on which this article is based thus aims at determining the shelf-life of the power bar specifically for the n-hexanal production during storage at various temperatures. The focus of this research is on one of the physicochemical attributes of shelf-life, which consists of the determination of oxidation rate.

MATERIALS AND METHODS

Product development

The main ingredients used to prepare the power bar were margarine, brown sugar, orange juice, cake flour, soy flour, soy milk powder, baking powder, and a variety of toppings. The power bars were prepared as follows: An oven was preheated to 160°C, then the margarine and brown sugar were placed in a saucepan, and heated gently until melted. The mixture was removed from the heat and the orange juice was added. Following that, the cake flour, soy flour, soy milk powder and baking powder were sifted together and the melted margarine mixture was added. The mixture was then pressed in a lamington pan of 20 × 30 centimetres (cm) and baked for 15 minutes at 160°C.

Shelf-life testing

Components of shelf-life testing included assessing the physico-chemical and microbiological attributes of the prepared energy bars. The physico-chemical attributes consisted of the determination of oxidation rate. This experiment was conducted at three accelerated shelf-life test temperatures and this information was used to model the shelf-life of power bars at ambient conditions. The Arrhenius model (Labuza and Riboh 1982), supplemented by the linear model (Robertson 1993), was used to predict the shelf-life of power bars at ambient conditions.

Storage conditions

For storage under various conditions, power bar samples, weighing 100 grams (g) each, were placed in wide-mouth 473 millilitre (ml) mason jars (Ball, Alltrista Corp., Muncie, IN). The storage temperatures were 40, 50 and 60°C, respectively, and the water activity (aw) values of the samples were adjusted to the range of 0.29-0.38 using moisture-absorbent sachets (silica gel pillow pack, Desiccare Inc., Santa Fe Springs, CA). Temperatures and relative humidity of the chambers were monitored using a data logger (model TL 120, Dickson Company, Addison, IL) as described by Lee et al. (2002).
Determination of n-hexanal

Previous studies have shown that the n-hexanal level correlates well with the rancid attribute by comparing sensory and instrumental methods (Lee et al. 2002). The hexanal level was also found to be a good indicator of oxidative rancidity in many other food systems (Bovell-Benjamin et al. 1999). We used the n-hexanal variation to predict the shelf-life of the energy bars. n-Hexanal was determined as the 2,4-dinitrophenylhydrazine derivative with high performance liquid chromatography (HPLC), according to the method of Matoba et al. (1985), except for the use of perchloric acid instead of phosphoric acid. Ten g of energy bar samples were ground in a mortar with liquid nitrogen, and then homogenised at room temperature in 0.5 ml of perchloric acid with a homogeniser of the Potter-Elvehjem type. The homogenate was used for determining n-hexanal.

The analyses were performed using the Perkin Elmer HPLC set (Norwalk, USA) comprising of a LC 200 pump, a LC 200 autosampler, LC Column Oven 101 thermostat and LC 235C diode-array detector attached to a Perkin Elmer Turbochrom Chromatography Workstation version 4.1. The Pecosphere C18 150 mm × 4.6 mm, 5 µm particle size reverse phase column (Perkin Elmer, Norwalk, USA) with a column guard (4 × 200 mm; GL Sciences) was used at the flow rate of 1.0 ml min⁻¹ and column pressure 6.5 MPa (950 psi). The injection volume was 100 µl and the derivative was eluted with acetonitrile/water/tetrahydrofuran (75: 24: 1, v/v/v) at a flow rate of 1.0 ml/min and detected at 350 nm.

Data analysis

Fifteen samples were prepared and each experiment was carried out in triplicate. Statistical analysis of items was performed by using Excel 2007 and Splus 2000 for Windows 2001.

RESULTS AND DISCUSSION

Theoretical approach to estimate initiation periods of power bar samples

The Arrhenius relationship (Labuza 1982a) or the linear model (Robertson 1993) can be used for describing how much faster or slower a reaction will go if the sample is held at other temperatures (i.e. effect of temperature on k). These models were used in this study to extrapolate energy bar shelf-life results from accelerated tests at higher storage temperatures. The aim was to estimate power bar shelf-life results under ambient storage conditions. In the literature, most food-quality deterioration was found to fit either a zero- or a first-order mathematical expression (Labuza 1982a): -dA/dt = k(A)n where A = a quality attribute measured in some units, n = the reaction order, and k = the rate constant. For either zero- or first-order deterioration, Robertson (1993) also showed that k1tS1 = k2tS2 where k1 = rate constant at T1, k2 = rate constant at T2, tS1 = shelf life at T1, and tS2 = shelf life at T2.

Application to the determination of initiation and propagation periods of energy bar

The rate of oxidation for the power bar was determined by plotting the n-hexanal level versus (vs) storage time. This is in accordance with the fact that the n-hexanal level correlated well with the rancid attribute as demonstrated by Lee et al. (2002). Hexanal levels also proved to be a good indicator of oxidative rancidity in many other food systems (Bovell-Benjamin et al. 1999). From the n-hexanal level vs. time plots, linear regressions are derived together with the data points of the initiation period and the propagation period. The x-value of the intercept of these linear regressions was determined to be the estimated end of the initiation period. This method of analysis was performed for all samples at each temperature. Fig. 1 shows n-hexanal level vs time plots for energy bars stored at 40, 50 and 60°C respectively.

The estimated initiation period at 40°C was found to be five weeks (Fig. 1). The same method was used to estimate the initiation periods at 50 and 60°C. Initiation periods of three weeks for samples stored at 50°C and one week for samples stored at 60°C were recorded (Fig. 1). Because the rate of oxidative rancidity accelerates at the onset of the propagation period, the estimated initiation period could be regarded as a conservative shelf life (ts) at the three accelerated storage temperatures. Table 1 shows regression equations and R² values for the initiation and propagation periods together with corresponding estimated initiation periods (ts) in weeks for all samples at storage temperatures of 40, 50 and 60°C, respectively.

**Table 1** Regression equations and R² values for initiation and propagation periods of lipid oxidation and the estimated initiation periods for power bar samples stored at 40, 50 and 60°C.

<table>
<thead>
<tr>
<th>Storage temperature (°C)</th>
<th>Regression equation and R² for initiation period</th>
<th>Regression equation and R² for propagation period</th>
<th>Estimated initiation period (ts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>y = 32.5x - 5; R²=0.87</td>
<td>y = 684.1x - 2797.1; R²=0.84</td>
<td>5 weeks</td>
</tr>
<tr>
<td>50</td>
<td>y = 60x - 63.33; R²=0.98</td>
<td>y = 646.8x - 1780.4; R²=0.99</td>
<td>3 weeks</td>
</tr>
<tr>
<td>60</td>
<td>y = 100x; R²=1</td>
<td>y = 870x - 1817.3; R²=0.98</td>
<td>1 week</td>
</tr>
</tbody>
</table>
CONCLUSIONS

A power bar, for immune-deficient patients was developed at the Vaal University of Technology. As part of this product development, its shelf-life at various temperatures was screened. The results from accelerated shelf-life testing conducted at higher temperatures were extrapolated to predict the shelf-life at normal storage conditions. The results indicated that energy bars may be stored for 168 days at 4 ± 1°C, 105 days at 9 ± 3°C, 56 days at 15 ± 5°C, 21 days at 30 ± 2°C, and only 6 days at 42 ± 3°C. This research was conducted on small samples and did not consider other factors like packaging, microbial or enzymatic post-deterioration, which can influence both nutritional and hygienic qualities of the newly developed power bar. There is thus a need for more research to validate this very first data on the power bar for immune-deficient patients.

REFERENCES


