

CHAPTER V

EFFECT OF PACKAGING MATERIALS ON TEXTURAL PROPERTIES, WATER ACTIVITY AND MOISTURE CONTENTS OF *SUNNAH* CEREAL BAR UPON STORAGE

5.1 INTRODUCTION

Recent discoveries have shown that changes in dietary habits lifestyle and lifestyle of consumers influence nutritional requirements and nutrient intake; hence, a healthful plus wholesome diet is imperative to fulfil the essential requirements of human body (Mendes et al., 2013). Grden et al. (2008) reported that cereal bars are among the most advanced RTE products due to their natural ingredients and their wholesomeness that makes them make a positive contribution to human health. Cereal bars with the addition of *Sunnah* foods can supply essential additional nutrients; proteins, fibre, lipids, minerals and vitamins. Consumption of cereals plays a crucial role in the inhibition of protracted illnesses like CHD, diabetes, colorectal cancer etc. Cereals are also considered as main functional ingredients in the cereal food industry (McKeivith, 2004; Charles & Louise, 2005).

RTE breakfast cereals and their products perform a significant function in the human diet through precise role and biological assistance to the human body; they are also regarded as the economically viable base of nutrients (Paul et al., 2010; Gretchmen, 1995). Consumers want wholesome (healthful), convenient, tasty snacks that satisfy hunger quickly until the next meal (Burn 2007). Cereal bars are food products that match these criteria and have continued to rise in sales according to ACNielsen Market Track (Burn, 2007). Consumers are searching for bars with a balanced

nutritional profile of calories (energy), lipid, protein, carbohydrate along with vitamins and minerals, including fibre (King, 2006).

Cereal bars are among the convenient and RTE products dominating larger space in the consumer market. They satisfy the hunger and also provide evidence as an excellence source of nutrients; hence, a suitable system of alternative meal (Catherine & Johnston, 2012). Ananthan et al. (2012) affirmed that diets based on whole cereals are increasing daily because of their numerous health benefits associated with them as they are an excellent source of antioxidants, vitamins and dietary fibre.

The nutritious energy bars are gaining more significance and acceptance in the world market in recent years and now the market is presenting variety of bars under diverse names. The various brands of bars offered in the world market with good organoleptic attributes and consumer attractiveness/appeal are referred by names like chewy granola bars, organic bars, muffin bars, choco bars, fruit filled bars etc. (Ananthan et al., 2012). Cereal bars are regarded as snacks with good nutritional and sensory features because of their high contents of carbohydrates, minerals, proteins and vitamins (Estevez et al., 2000).

Many reports have affirmed the importance of incorporation of fruits in cereal bars, in this study; *Sunnah* foods are being incorporated to enhance the nutritional value of the bars. *Sunnah* foods are extremely nourishing and their significance for human healthiness is referenced in the Holy Quran (Awan & Sohail, 1999). Flesh Date fruit (100g) contains 73.50g carbohydrate, 2.30g proteins, 1.50g ash and 0.20g fat. The dates also possess vitamins A, B₁, B₂, C, mineral elements, nicotinic acid and folic acid. They are regarded as excellent basis of energy majorly because of the presence of significant quantity of voluntarily digestible carbohydrate (Al- Shahib & Marshall,

2003). The nutritional benefits of dates and other *Sunnah* foods cannot be realized unless the developed product is liked by consumers.

Nanjundaswamy et al. (1976) stated that diverse fruits are being utilized to elaborate fruits bars; they are expedient, and entice all generations to meet their needs - protein and energy. Estevez et al. (2000) stated further that granolas contain diverse cereals, fruits and legumes as a key ingredient together with chocolates coatings, nuts or chips. The confectionary industry has made use of date paste as one of its main ingredients, reported by Alhamdan & Hassan (1999).

The growing/rising request for high quality RTE foods with long shelf lives has introduced the formulation of several composite foods; these RTE foods consist of various textures. Moisture movement is a fundamental predicament in these complex systems that involve no less than two phases with dissimilar water activity which are closest. It has been noted by researchers that water diffuses from the 'wet' phase to the 'dry' phase; this diffusion leads to irreversible changes in the organoleptic and microbial quantity of the composite food, hence a reduction in the shelf life of the RTE foods (Labuza & Hyman, 1998; Le Meste et al., 2002). Researchers have initiated methods to predict the water activity, a_w of the multicomponent food systems from their original chemical compositions (Gaurie, 2005; Ross, 1975). Roca et al. (2006) observed in their study that water migration in food products is the result of a number of coexisting moisture transport mechanisms, improved by the complexity of the food structure and its components such as the interaction of water with the food constituents (Zogzas et al., 1996).

Shelf-life is usually defined as the time during which a food product remain safe, comply with label declaration of nutritional data and retain desired chemical, sensory,

microbiological and physical characteristics when stored under the recommended conditions (IFST, 1993). Hence, to evaluate shelf-life objective indexes related to nourishment, microbiological or physicochemical attributes of food have to be typically measured (Wansink & Wright, 2006; Cardello, 1995). Labuza & Szybist (2001) stated that shelf-life is a function of environmental factors, time and vulnerability of product to quality change.

Chemical, physical, chemical and biological changes that occur throughout the food chain generally lead to product deterioration and these changes might in time compromise nutritional, microbiological or sensory quality. In many products changes in sensorial attributes arise generally before any risk to consumers' health is reached (Lawless & Heymann, 2010). Hough (2010) stated that the shelf-life of most foodstuffs is reduced by deviations in their sensory attributes. Precise forecast of shelf-life is indispensable to consumers and manufacturers. Increase in consumer's apprehension on healthy eating and making healthy food selections require inter alia, safe, convenient, fresh and superior quality foods (Giménez et al., 2012).

According to Loveday et al. (2009), there is a substantial time lag between manufacture and consumption; during this period, the product is transported and stored. In the course of the storage time, several chemical, physical and biological reactions occur sequentially and simultaneously. These reactions at times lead to negative impact on quality as observed by consumers. Shelf life, according to Loveday et al. (2009), is the length of time for which a product can be stored prior to the appearance of the first characteristics that consumers find unpleasant such as tough texture. Cereal bars is an intermediate-moisture food; they generally have water

activity in the range of 0.60-0.90, Roos (2001). This water activity is low enough to prevent the growth of most spoilage microbes (Jay, 1996).

Cereal bars are usually packed in metallised polyester films; they have a limited shelf life of three to four months (Ananthan et al., 2012). Loveday et al. (2009) stated that the shelf-life of a protein bar is often reduced by the development of a tough texture that consumer find unpleasant. The hardness development in protein rich bar may be attributed to the movement of moisture in addition to formation of most ordered secondary structure and lowering of surface hydrophobicity of protein particles. Zhou et al. (2008) proposed that hardening resulted from thio-disulfide interchange reaction during storage of cereal bars. Baier et al. (2007) cited that moisture migration acted as a driving force for the hardening of protein bars, though the end point and source of the migration was not specified. Baier et al. (2007) observed that the texture of protein bars changed markedly during storage because it had increased fractured stress.

Researchers have noted that RTE foods are highly prone to lipid oxidation, regardless of fat content; they develop considerable flavor and odour, reduced sensory assessment, nutritional quality and safety during storage, (Forss, 1995; Esterbauer, 1993; Kubow, 1992), all these reactions make the product unpalatable. It is therefore imperative to extend the shelf life and preservation of RTE foods through proper packaging. Packaging plays an important function in assessing the foods' shelf lives foods because it functions as oxygen's barrier cum loss/gain of moisture in foods (Khan et al., 2008; Sharma et al., 1990). Choosing a suitable material for packaging is very important to guarantee utmost product quality throughout storage to inhibit lipids oxidation (Seacheol & Zhang, 2005).

In this context, *Sunnah* cereal bar containing glutinous rice flakes as the main cereal ingredient, dates, figs, raisins, saffron, habbatus sauda and binders (honey and glucose syrup) was developed and shelf stability was evaluated in metallised polyester film, (MP), aluminium foil (AF), polyethylene terephthalate (PET) and Nylon (polyamide) under ambient temperature conditions for 120 days, which should be enough to detect any reactions in the formulations. Thus, this research aimed to investigate the influence of different packaging materials on 120-day stored *Sunnah* cereal bar's quality.

5.2 MATERIALS AND METHODS

5.2.1 Sample Preparation

The glutinous rice and other ingredients: glucose syrup, honey, the dried fruits (dates, figs and raisins), black cumin and saffron were purchased at TESCO, Nilai, Malaysia. All the chemicals used for the study were of analytical reagent grade.

5.2.2 Preparation of puffed glutinous rice

Puffed glutinous rice was prepared as described in Chapter 3 of this thesis.

5.2.3 Preparation of puffed glutinous rice cereal bar

The preparation has been described in chapter 3. It followed the same procedure used by Freitas & Moretti (2006) with modification.

5.2.4 Texture Profile Analysis (TPA) of *Sunnah* Cereal bars stored under different Packaging Materials

Hardness and fracturability of the *Sunnah* cereal bars were determined freshly and at the end of 120 days of storage using Texture Analyzer (Model TA.XT2 plus, Stable

Microsystems, Surrey, UK) with a 25kg load cell. The Texture Expert programme version 6.0.3.0 was used for data analysis. It was carried out in accordance with Piga et al. (2005) with slight adjustments. Textural determinations were carried out on the six formulations (Table 12, chapter 3) of the *Sunnah* cereal bars by using a blade set with knife edge for a cut test (model HDP/WBR), a 4mm diameter 3-point bend rig probe for bend test (model P/4), (Table 16).

The bars were bended to determine structural properties present inside or on the surface of the samples. The samples for the bend test were positioned centrally on heavy duty plate form under the three-point bend rig probe, TA - 45. The load cell and the probe were together standardized before the test. *Sunnah* cereal bars selected were 11cm in length and 1.50cm thick, in order to have standardized samples. Textural determinations were carried out on the six formulations after being stored in four different packaging at day 120. Measurement of hardness of the *Sunnah* cereal bars by bending involved plotting force (N) versus time (seconds). The highest force (g) was used as an indicator of hardness for bend test and maximum distance was termed fracturability of the cereal bars (Figure 10a and 10b).

Texture profile analysis was measured according to the typical TPA curve as reference (Figure 10a & 10b). TPA is common test; it uses the principles of compression. It is also called an "imitative test" as it tries to imitate the action of the jaw by compressing the sample piece twice in an exchange motion hence it is called the "Two Bite Test". The force time-time curve obtained from TPA provides several textural parameters that are identified to correlate well with sensory evaluation limits.

Table 16: TA.XT2 plus settings for comparison of texture (hardness and fracturability) of different formulations of *Sunnah* cereal bars by 3-point bend probe (TA - 45)

Mode:	Measurement compression	force	in
Option:	Return to start		
Pre-test speed:	1.00 mm/s		
Test-speed:	3.00 mm/s		
Post-test speed:	10.00 mm/s		
Distance:	8.00 mm		
Trigger force:	50g		
Tare mode:	Auto		
Data acquisition rate:	500 pps		

Figure 10a: Typical Textural Analysis Profile Curve

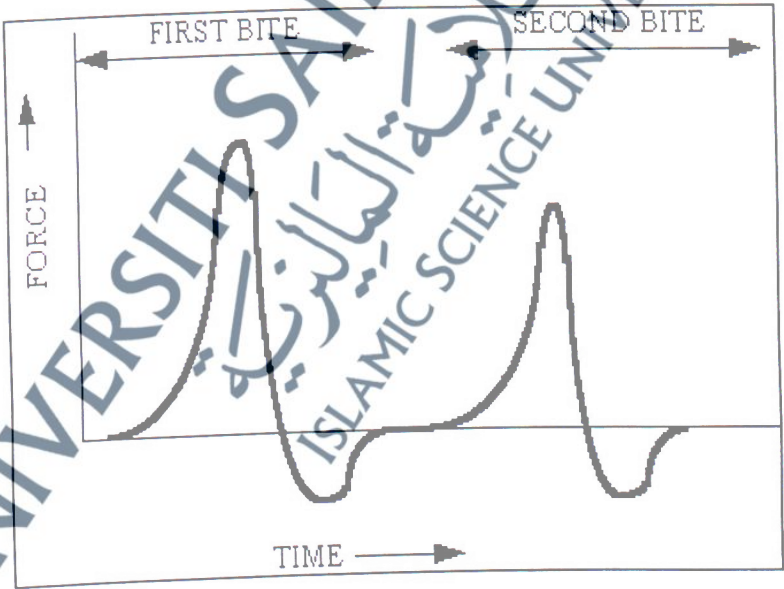
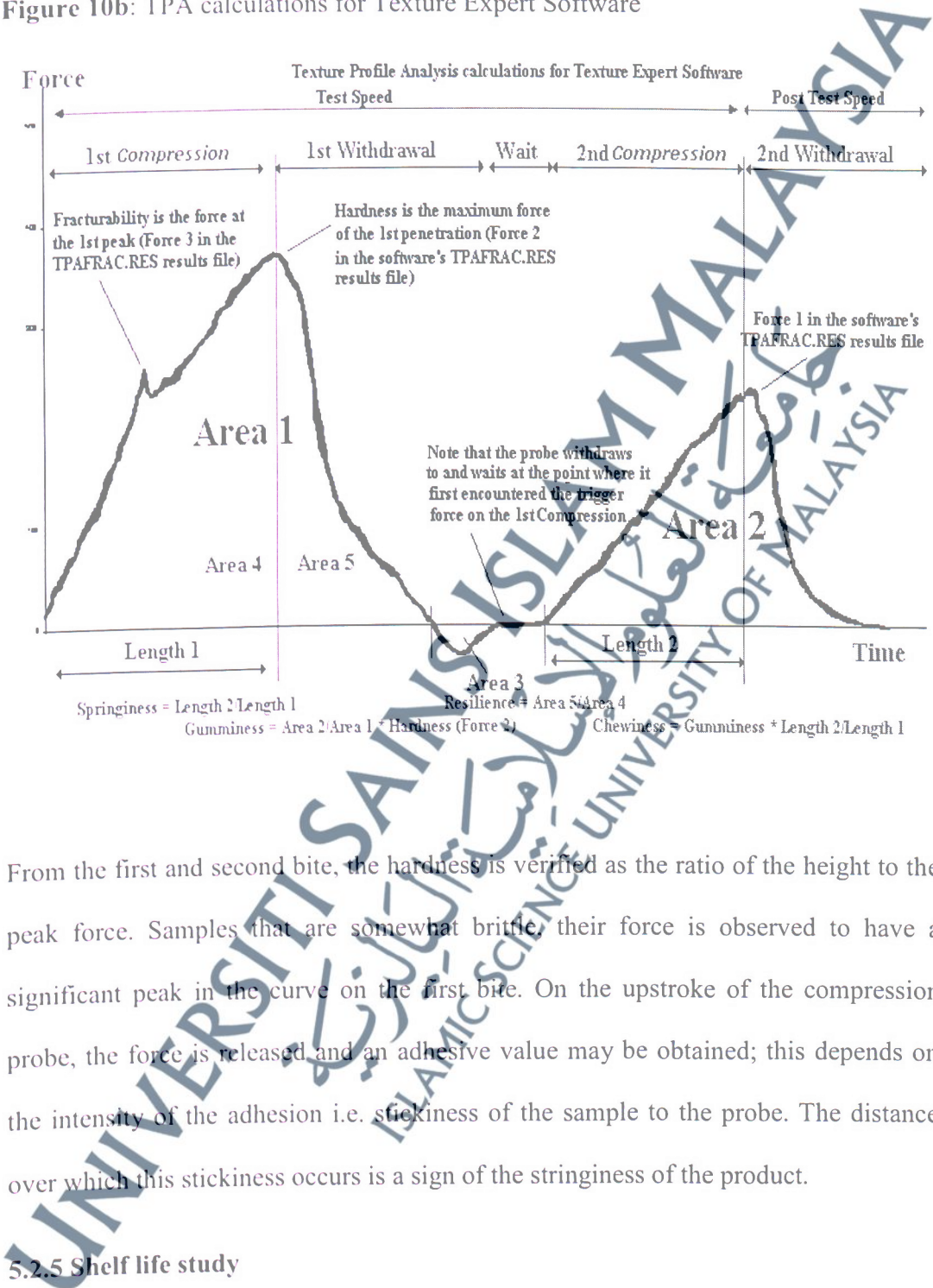


Figure 10b: TPA calculations for Texture Expert Software



From the first and second bite, the hardness is verified as the ratio of the height to the peak force. Samples that are somewhat brittle, their force is observed to have a significant peak in the curve on the first bite. On the upstroke of the compression probe, the force is released and an adhesive value may be obtained; this depends on the intensity of the adhesion i.e. stickiness of the sample to the probe. The distance over which this stickiness occurs is a sign of the stringiness of the product.

5.2.5 Shelf life study

For the shelf life study of *Sunnah* cereal bars, each of the six formulations of the bars were packaged manually in four different packaging materials (metallised polyester

film, aluminium foil, polyethylene terephthalate and Nylon (polyamides) and stored under ambient temperature conditions for 120 days. After which the textantures, moisture contents and water activity of the formulated samples were measured.

Water activity of the *Sunnah* cereal bars was evaluated by the water activity (Aqualab Decagon, USA). The bars were placed in the disposable cup of the metre; then placed in the water activity metre. The sample chamber lid was sealed over the sample. The water activity was then measured after about 10-15 minutes wait. The moisture contents of the stored samples were determined as described in chapter 3 of this study.

5.3 RESULTS AND DISCUSSION

5.3.1 Textural attributes of *Sunnah* cereal bars

The texture analyzer mimics the human chewing and determines the tenderness of a food product, an important sensory feature (Silva et al., 2003). One of the most important characteristics is texture; it determines the total feature and suitability of a food produce by the consumers. The two most significant texture parameters were studied. They were hardness (the maximum peak force during the first compression; first bite. It is also known as the force needed to crumble a food sample when placed on a 3-point bend rig) and fracturability, the second parameter, the degree of deformation when placed on a 3-point bend rig; a measure of the level of fracture failure under compression (Rehman et al., 2012; Foster et al., 2011).

There was no significant difference ($P>0.05$), (Table 17), among the different packaging materials/different formulations. It showed that the samples with the highest contents of *Sunnah* foods had the initial maximum hardness (509.27g) and (488.67g). The results were comparable to the results obtained in the work of Rehman

and his co-researchers (2012). They obtained hardness that ranged from between 315.58 and 420.52g. The hardness results of this work varied between 447.50 and 509.27g. It could be concluded that the hardness values were directly proportional to the amount of *Sunnah* foods used in the formulations. However, decreasing trends was observed in the study of apricot-date bars by Rehman et al. (2012). Maximum value of hardness was obtained in the apricot-date bar with minimum amount of fruits and vice-versa. The difference in the observation could be probably traced to the difference in fruits used for the study and the binders used in the work of Rehman et al. (2012).

Table 17: Hardness (g) and fracturability (g) of freshly produced *Sunnah* cereal bars

Formulations						
Parameters (g)	A	B	C	D	E	F
Hardness	509.27 ^a	488.67 ^a	447.50 ^a	480.93 ^a	488.63 ^a	486.07 ^a
Fracturability	41.41 ^a	43.72 ^a	37.72 ^a	43.98 ^a	41.93 ^a	45.01 ^a

Means followed by the same letters in rows and columns do not differ by Tukey’s test (P<0.05).

A (*Sunnah* foods – 450g, honey – 100g, glucose syrup – 70g), **B** (*Sunnah* foods – 450g, honey – 50g, glucose syrup – 140g), **C** (*Sunnah* foods – 300g, honey – 100g, glucose syrup – 70g), **D** (*Sunnah* foods – 300g, honey – 50g, glucose syrup – 140g), **E** (*Sunnah* foods – 150g, honey – 100g, glucose syrup – 70g), **F** (*Sunnah* foods – 150g, honey – 50g, glucose syrup – 140g).

The hardness of the *Sunnah* cereal bars in this study, (Table 17) was lower than the amounts obtained in the work of Shaheen et al. (2013); they evaluated the physicochemical characteristics of date based fibre enriched fruit bars. They obtained

hardness values that ranged from 1307.40 to 2368.90g. Different fruits were added at the same amount in their formulations. It was ascertained in their study that the sample with no added fruits had the highest hardness while the sample with variety of fruits had the lowest hardness. This corroborated the observation that addition of varieties of *Sunnah* foods reduced the hardness of the *Sunnah* cereal bars. This was the reason the hardness of the cereal bars in this work were lower to those obtained in their study.

Munhoz et al. (2014) reported that high hardness values of cereal bars were not usually related to the low acceptability of the product as evaluated by sensory evaluation. Usually, cereal bars being a product that was prepared with fibre content led to the product that was more dense and hard. Freitas & Moretti (2006) stated that further hardness did not infer that the product had lower acceptance. The panelists gave the best texture scores for formulation C, this agreed with the instrumental analysis as indicated that the sample with average texture (447.50 g) tended to be a little bit softer and more liked by the consumers. Munhoz et al. (2014) reported that cereal bar containing bocaiuva obtained values of 161.54N and 117.48N for their two formulations. The variation observed between the forces exerted by the texture analyzer to break the *Sunnah* cereal bar was as a result of the diversity of structures in the formulations (puffed glutinous rice, black cumin, dates, figs, etc.). Freitas and Moretti (2006) stated further cereal bars had a heterogeneous mixture structure with respect to the shape and size of ingredients. There were also variations in thickness along the length of cereal bars, thus the variations in the hardness of the bars.

Comparing with other studies, the result of hardness obtained in this study was lower than the results obtained by Aigster et al. (2011) who formulated resistant starch-

supplemented cereal bars and obtained values of 908g and 1492g for the two formulations in their study. The hardness levels were different because of the ingredients used. Resistant starch cereal bars undoubtedly presented higher values than *Sunnah* foods used in the formulation of bars in this study. Sun-Waterhouse et al. (2010) elaborated cereal bars with apple DF and inulin. The force exerted to penetrate the apple DF and inulin cereal bars were 61.72N and 44.05N, respectively. Inulin, like honey facilitated the reduction of cereal bar hardness. This was apparent in formulation C hardness and fracturability, 447.70 g and 37.72 g respectively. The fracturability of formulations A, C and E, also followed this trend. The difference observed in the hardness of *Sunnah* cereal bars and those developed by Sun-Waterhouse & colleagues (2010) could be traced to the type of binders used. The apple DF and inulin in their bars reduced the hardness of the bars (Sun-Waterhouse, et al., 2010).

Pathare et al. (2012) in their work revealed that the hardness values of their bars ranged from 56.00N to 284.00N. The difference in hardness values when compared to the *Sunnah* cereal bars was traced to the production method of their bars by fluidized bed granulation (Pathare et. al., 2012). This process had a great effect on the level of the hardness. Souza et al. (2014) formulated a gluten-free cereal bar with whole flour of pseudo-cereals new cultivars. They obtained values of hardness that varied between 19.64g and 24.91g. The hardness was inversely proportional to the amount of puffed cereal used in the formulations. The hardness of the *Sunnah* cereal bars in this work followed the same trend; it ranged between 509.27 g and 447.5 g.

In other words, the hardness increased progressively and proportionately with the increase of cereal compositions; this corroborated with the work of Enriquez et al.

(2003). Hardness and fracturability are characteristics of high importance in determining cereal bar quality parameters. Maximum hardness and fracturability of protein date bars developed by Nadeem et al. (2012) were 2887.31g and 74.70mm respectively. The values obtained in this present research were lower than the values obtained by Nadeem & co-researchers (2012) because the proteinous component had a greater effect on texture of food products (Loveday et al., 2009). Zhou et al. (2008) suggested that hardness of protein bar resulted from interchange of thiol-disulphide reactions during storage; this also leads protein aggregation, network formation and cross-linking which could result in a hard texture.

Fracturability, on the other hand followed the trend of Rehman et al. (2012), fracturability of their bars ranged from 64.25 to 65.53g. The fracturability values of the *Sunnah* cereal bars varied between 37.72 and 45.01g, (Table 17). The higher the amount of *Sunnah* foods added in the formulation, the lower the fracturability. It was stated by Rehman et al. (2012) that moisture content of the bars were increased with the addition of dried fruits which caused the reduction in fracturability of the bars.

Fracturability in the work of Shaheen et al. (2013), also followed the same pattern, (Table 17), fracturability in their bars varied from 77.60 to 79.38g. Also, sample with no added with had the maximum value of fracturability in the work of Shaheen and co-authors (2013). Fracturability was affected by added fruits. The fracturability of the *Sunnah* cereal bars shown in Table 10 revealed that formulation F (45.01 g), one of the formulations with the lowest *Sunnah* foods had the highest fracturability. This was in accordance with the findings of Shaheen et al. (2013) and Rehman et al. (2012).

Foster et al. (2011) studied identification of multiple compartments present during mastication of solid. They obtained a value of 210.30 and 310.30N for cereal bar and

muesli bar respectively. The authors stated that lower hardness was attributed to fracture failure on compression. Therefore, their bars had lower hardness compared to the *Sunnah* cereal bars due to the above-mentioned reason. Fracturability values that varied between 20.50Pa and 201Pa were reported for texture of protein bar by Loveday et al. (2010). It was revealed that addition of fruits reduced fracturability which this study had reinforced.

5.3.2 Shelf life results of *Sunnah* cereal bars

The three parameters measured with the bars packaged and stored for the shelf life study of *Sunnah* cereal bars, in four different packaging materials viz.: metallised polyester (MP), nylon (polyamide), aluminium foil (AF) and polyethylene terephthalate (PET) were textural parameters (hardness and fracturability), moisture contents and water activity, a_w . They were evaluated after 120 days of storage in the packaging materials at ambient temperature.

Table 18: Moisture contents (%) of *Sunnah* cereal bars after 120 days of storage

Packaging Materials	Formulations					
	A	B	C	D	E	F
Nylon	21.670 ^a	19.696 ^a	16.350 ^{ab}	17.820 ^a	15.263 ^{ab}	14.027 ^{ab}
AF	17.890 ^a	16.494 ^a	12.213 ^b	12.857 ^a	9.120	9.560 ^c
MP	19.807 ^a	19.530 ^a	15.703 ^{ab}	14.570 ^a	11.653 ^{bc}	11.100 ^{bc}
PET	21.253 ^a	18.716 ^a	18.533 ^a	18.550 ^a	19.347 ^a	16.053 ^a

Means that do not share a letter in rows and columns are significantly different ($p<0.05$).

Abbreviations: AF (Aluminium foil), MP (Metallised polyester), PET (Polyethylene terephthalate).

5.3.2.1 Moisture content of the 120-day stored *Sunnah* cereal bar

At the end of storage of the *Sunnah* cereal bars for 120 days, the moisture contents recorded in the packaging materials ranged from 14.027 to 21.670% for nylon, 16.053 to 21.253% for aluminium (AF), 11.100 –19.807% for metallised polyester and 9.120 to 18.716% for polyethylene terephthalate (PET), (Table 18).

It was observed that the composition of fruits had a massive effect on the moisture contents. The higher the *Sunnah* food contents, the higher the moisture contents. Table 18 shows that addition of *Sunnah* foods had significant ($P<0.05$) effect on moisture. Comparison among the different packaging materials showed that aluminium foil (AF) was the best packaging materials in term of moisture among the packaging materials used for the *Sunnah* cereal bars. There was a significant difference in the

moisture contents among the different formulations of the bars. Formulations **E** and **F** had the lowest *Sunnah* food contents (150 g each) and they had the lowest moisture contents, 9.12% and 9.56% respectively. An observation of the formulations across the packaging materials showed that the formulations with the lowest *Sunnah* food compositions (150 g) had the lowest moisture contents (9.12% and 9.56%) after 120-day storage. The same trend was observed in the findings of Rehman et al. (2012) who reported that addition of dehydrated apricot paste in the formulations of their bars increased the moisture contents.

Metallised polyester also showed a good barrier to moisture migration in the *Sunnah* cereal bars during storage. Formulation **F** had the lowest moisture content (11.10%) because of its lower *Sunnah* food composition. It also contained lower amounts of honey. The higher glucose syrup content might have assisted the sample to be more compact. Loveday et al. (2009) reported that substance like glucose syrup would decrease moisture contents by removing water from the formulation.

However, polyethylene terephthalate (PET) came next after metallised polyester. The moisture contents of the formulations varied from 16.053 to 21.253%. More so, there was no significant difference ($P>0.05$) among the formulations in term of moisture contents with the PET. In term of moisture absorption during storage, metallised polyester was next after AF in providing excellent barrier to moisture during the storage of the *Sunnah* cereal bars for 120 days.

However, rate of moisture migration differed among the packaging materials. Silva & co-researchers (2013) showed that there was decrease in moisture contents in their bars after storage for 120 days. Moreover, there was a great difference in the cereal base used. Cassava flour was used in the study of Silva et al. (2013) while the cereal

base in this study was puffed glutinous rice which had different properties from cassava flour as a result of different compositions of cassava flour and puffed glutinous rice.

Ananthan et al. (2012) developed a shelf life stable protein rich composite cereal bar; the bar was packaged in three different packaging materials, namely polypropylene, paper aluminium polyethylene and metallised polyester. The authors reported that cereal bars were usually packed in metallised polyester films. Furthermore, they found out that the most suitable for packaging cereals with respect to its stability and acceptability was metallised polyester film with vacuum. The metallised polyester package in this study also showed suitable results despite the fact that the packaging was not done under vacuum.

As shown in Table 18, nylon (polyamide) had the poorest moisture barrier. Nylon (polyamide) presented the highest moisture contents that ranged from 14.027 to 21.670%. There was a significant difference ($P < 0.05$) among the formulations with nylon as a packaging material. All the formulations showed increase in moisture contents during the 120-day storage period, as also found by Mendes et al. (2013). The authors formulated granolas with nuts of baru and fruit peels. The formulated bars were packaged in different PET packaging materials. It was concluded in their study that there was a slight increase in moisture contents of the formulations.

Freitas & Moretti (2005) studied the stability of cereal bars with high vitamin and protein levels using three packaging films (PET met/PEBD; PET/PEBD/Al/PEBD and PET/PEBD). These materials had diverse barrier features and the bars were stored for 180 days. The authors observed that the moisture contents of the cereal bars increased, the moisture contents increased from 10.19% to 12.37%, they concluded that the best

packaging material was PET laminated with aluminium. The aluminium foil as a packaging material in this study corroborated this trend. The moisture contents in their study varied from 10.19 to 12.37%; this was in agreement with the values found in AF materials (9.120 – 18.716%) in the present study. The metallised polyester (11.100 – 19.807%) also showed a favourable result but polyethylene terephthalate (PET) but nylon differed, it ranged from 16.053 – 21.253% and 14.027 – 21.067% respectively.

A critical look at the moisture contents revealed that asides formulations A and B, MP and AF as packaging materials had the moisture contents of the formulations reduced as reported by Silva & co-authors (2013). The moisture contents of their formulated bars reduced from 12.00 to 9.79% for a 120-day storage. Mendes et al. (2013) had a reduction of 11.85 to 11.76% when their bar samples were also stored for 120 days in a PET packaging materials.

5.3.2.2 Water activity of the 120-day stored *Sunnah* cereal bars

The a_w values denote the availability of moisture/water in a food product that usually lead to microbial spoilage (Lobato et al., 2011). Table 19 shows the water activity of the bar formulations after 120-day storage. Water activity is an indicator of storage. The water activity of all the six formulations was < 0.620 , the upper limit set for yeast and mold tolerance, as stated by Troller and Christian (1978). The formulations with increase in water activity followed the findings that reported that water activity of cereal bars increased significantly with time with values that varied between 0.22 to 0.45 (<http://www.dupontteijinfilms.com>).

Table 19: Water activity of *Sunnah* cereal bars after 120 days of storage

Packaging Materials	Formulations					
	A	B	C	D	E	F
Nylon	0.574 ^b	0.591 ^a	0.563 ^b	0.599 ^a	0.587 ^a	0.595 ^{ab}
AF	0.543 ^d	0.586 ^a	0.533 ^c	0.558 ^c	0.549 ^b	0.585 ^{bc}
MP	0.559 ^c	0.551 ^b	0.543 ^{bc}	0.576 ^b	0.559 ^b	0.570 ^c
PET	0.587 ^a	0.567 ^{ab}	0.593 ^a	0.592 ^a	0.589 ^a	0.609 ^a

Means followed by the same letters in rows and columns do not differ by Tukey's test ($P < 0.05$).

A (*Sunnah* foods – 450g, honey – 100g, glucose syrup – 70g), B (*Sunnah* foods – 450g, honey – 50g, glucose syrup – 140g), C (*Sunnah* foods – 300g, honey – 100g, glucose syrup – 70g), D (*Sunnah* foods – 300g, honey – 50g, glucose syrup – 140g), E (*Sunnah* foods – 150g, honey – 100g, glucose syrup – 70g), F (*Sunnah* foods – 150g, honey – 50g, glucose syrup – 140g).

There were significant differences ($P < 0.05$) among the formulations packed in aluminum foil. It could be observed that all the samples with higher honey compositions had lower levels of water activity. This was in line with the findings of Brandt (2000) that reported that binders could hold in moisture which could help to keep the bars fresher and long-lasting. The reduction in moisture reduced the water activity of the samples (0.597 to 0.543). Sun-Waterhouse et al. (2010) observed that binders like honey and glucose syrup facilitated an increase in shelf life as this was evidently partly due to decrease of water activity. They reported further that honey with other binders often modified water activity in the fillings of confectionery. Water activity determinations assist in prediction of food mechanical properties, stability and shelf life (Sun-Waterhouse et al., 2010) and reported that a fibre-enriched snack bar

filling water activity value, a_w , reduced to 0.440. The values in this study were higher than theirs because of the *Sunnah* foods composition and the types of binders. However, all the values in this study after 120 days of storage were below 0.700; this indicated low risk of spoilage microorganisms' proliferation and pathogenic spoilage indicating good shelf life (Beuchat, 1981).

Furthermore, Moura et al. (2013) in the acceptability and shelf life study of a light fibre-rich banana and acai bar found that the water activity reduced from 0.704 to 0.689 in 90 days. Some of the water activity values of the *Sunnah* cereal bars followed this assertion (0.543 – 0.609). Analysing each of the four packaging materials with respect to the formulations, it could be observed that formulations A and C packaged in nylon had reduced a_w during the storage period. Formulations B, D and F had increase in a_w while formulation E remained the same.

Formulations A, C, D and E packed in AF showed reduced water activity (0.543, 0.533, 0.558 and 0.549 respectively) while B remained the same (0.586) and F had its water activity increased (0.557 to 0.585). Metallised polyester seemed to be the best packaging material with respect to water activity. Only formulation F had increased water activity (0.557 to 0.570) after the 120 days of storage. Formulation F had higher glucose syrup content than honey; this might be responsible for moisture absorption that tends to increase its water activity. PET as a packaging material was good as a packaging material for formulations A and B in term of water activity. Other formulations: C, D, E and F, all had increase in the water activity values. This showed that PET had little inhibition/barrier against moisture absorption. The reduction of water activity during storage followed the results obtained in the work of Silva et al. (2013), the water activity values of the cassava flour based cereal bar reduced during

the storage period. The results obtained in this present study were lower than those found in the research carried out by Aigster et al. (2011), they used multilayered flexible metallised packaging which was reported to have excellent oxygen barrier characteristics.

Aigster et al. (2011) detected an increase in the water activity values of resistant-starch cereal bars after 28-day storage period. The preliminary and final a_w of the *Sunnah* cereal bars were lower than the values reported by Aigster & co-authors (2011), (0.690) in cereal bars, this considerably increased over the first week of storage up to the value of 0.770. A high preliminary result of water activity value of 0.650 was also obtained by Loveday et al. (2009) in protein bars during storage of 50 days. These results emphasized the magnitude of utilising more automated procedures and more suitable films, metallised polyester and aluminium foils used for the *Sunnah* cereal bars. These two packaging materials were better than nylon (polyamide) and polyethylene terephthalate (PET) because of their good moisture barriers.

The variation between initial and final water activity during the storage period of the bars could be attributed to changes in humidity, which was not manipulated, or the absence of homogeneity in a heterogeneous multicomponent food products. Furthermore, Lewicki et al. (2004) reported that the changes in the water activity figures (0.283 – 0.651) that were likely responsible for affecting the mechanical features of the bars might be related to the disparities in the microstructure and chemical constituent of the cereal bars. Freitas & Moretti (2006) produced and characterized cereal bars with oat, textured soy protein and wheat germ. They reported a final value that was lower than a_w values in this study (0.637) for their cereal bars.

Water activity (a_w) determinations assist to predict the mechanical features, stability and shelf life of the cereal bar.

5.3.2.3 Textural Properties of the 120-day stored Sunnah cereal bars

The shelf life study of a food product involves submission several samples of the food products, in this study, *Sunnah* cereal bars, were submitted for a sequence of tests over a lengthy period of time in order to ascertain their limits (Grizzotto, 2006). Wright (2004) reported that shelf life is a factor of vital importance; it defines the storage period in which foodstuffs with high initial quality stay protected for consumption. Texture is one of the most significant properties used by consumers to assess food quality (Hogan et al., 2012). The packaging materials were studied one by one.

The samples that were stored in the nylon (polyamide) all the samples had increase in their textures except formulations A (478.37g) and B (480.93g).

However, there was no significant difference ($P < 0.05$) in texture for all the formulations, (Table 20). Formulation C had the highest texture (hardness) value (540.10 g). This correlated with the result obtained with the sensory evaluation by the panelists before the bars were packaged. Formulations A and B had the highest fruits compositions, 450 g each, this might have contributed to the lowering of the hardness of the bars. The formulations showed highest compositions had higher moisture contents, (18.73%). Formulation A was the only sample that had reduced hardness (491.23 g) in the aluminium foil packaging.

Formulations A, B, and D had reduced/lower hardness in the metallised polyester packaging. Higher fruit compositions in formulations A and B could be a cause of their softer texture while lower honey or glucose syrup in formulation D might be

attributed to its lesser texture value. The interaction between the components of the bars, notably the fruits and the binders' interaction could cause moisture migration in the packaged bars.

Compared to other packaging materials, PET appeared non-suitable as a packaging material for the bars. Only formulations C and F had their hardness increased and remained firm. Formulations A, B, D and E in PET lost their firmness during storage because the four formulations had reduced hardness. Aigster et al. (2011) reported that resistant starch-supplemented granolas (cereal bars) had increase in their hardness of their textures. The hardness increased from 333 g to 487 g, 908 g to 1629 g, for control sample and 10 g/100 g resistant starch-supplemented granola in 21-day storage. However, 15 g/100 g resistant starch-supplemented granola had its hardness reduced from 1492 g to 1471 g over the 21 days of storage. There were no significant differences ($P<0.05$) among the samples in all the packaging materials for the fractuability of the samples during the storage period of 120 days.

Table 20: Hardness (g) of *Sumrah* cereal bars after 120 days of storage in four different packaging materials

Packaging Materials (g)	Formulations					
	A	B	C	D	E	F
Nylon	478.37 ^a	480.93 ^a	540.10 ^a	504.10 ^a	480.93 ^a	491.23 ^a
AF	491.23 ^b	524.70 ^{ab}	511.83 ^{ab}	501.53 ^{ab}	542.67 ^a	506.67 ^{ab}
MP	496.37 ^a	444.97 ^a	491.23 ^a	450.10 ^a	473.23 ^a	478.37 ^a
PET	488.63 ^{ab}	488.53 ^{ab}	555.53 ^a	450.10 ^b	488.53 ^{ab}	516.93 ^{ab}

Means in rows and columns that do not share a letter are significantly different ($P<0.05$).

Table 21 Fracturability (g) of *Sunnah* cereal bars after 120 days of storage in four different packaging materials

Packaging Materials (g)	Formulations					
	A	B	C	D	E	F
Nylon	43.72 ^a	41.41 ^a	43.55 ^a	52.98 ^a	44.23 ^a	43.21 ^a
AF	39.86 ^a	42.95 ^a	43.98 ^a	46.04 ^a	44.24 ^a	32.66 ^a
MP	42.69 ^a	41.99 ^a	42.44 ^a	41.41 ^a	27.95 ^a	34.46 ^a
PET	46.04 ^a	34.72 ^a	42.43 ^a	42.66 ^a	36.01 ^a	44.24 ^a

Means followed by the same letters in rows and columns do not differ by Tukey's test ($P<0.05$).

A (*Sunnah* foods – 450g, honey – 100g, glucose syrup – 70g), **B** (*Sunnah* foods – 450g, honey – 50g, glucose syrup – 140g), **C** (*Sunnah* foods – 300g, honey – 100g, glucose syrup – 70g), **D** (*Sunnah* foods – 300g, honey – 50g, glucose syrup – 140g), **E** (*Sunnah* foods – 150g, honey – 100g, glucose syrup – 70g), **F** (*Sunnah* foods – 150g, honey – 50g, glucose syrup – 140g).

Table 20 and 21 showed the hardness and fracturability of the cereal bars. Changes in texture were reported in numerous cereal bars' shelf life studies performed by various researchers. Granolas could become hard (Loveday et al., 2009) or lose compact texture upon storage. The texture of the protein bars changed substantially during storage; the fracturability increased from 20.5 Pa on the first day to 201 Pa on day 50 (Loveday et al., 2009). Baier et al. (2007) found a very similar trend of hardening in protein bars stored at 37°C and water activity of 0.11 or 0.42 for 28 days. The authors stated further that protein bars stored at water activity of 0.80 hardened for nearly 4 days and softened afterwards. The shelf life of protein bars is often limited by their inclination to become unacceptably hard during storage (Loveday et al., 2009). Taillie

(2006) reported bar hardening could become detectable after 2 to 3 months and unacceptable after 4 to 6 months.

Hogan et al. (2012) reported in their study that it is generally acknowledged that the discontinuity in the osmotic potential between dissimilar components or micro-regions is the driving force for hardening. The initial water activity of the all the *Sunnah* cereal bars (0.557 – 0.597) were lesser than that found by Aigster et al. (2011) (0.69), in granola bars. A high original value (0.65) was also obtained by Loveday et al. (2009) in protein bars through storage 50-day at 20 °C. The findings emphasised the significance of using extra automated procedures and additional suitable packaging layers rather than the manual methods used in this research.

The instrumental TPA properties for the cereal bars corroborated the results of the panelists for the texture of formulation C which was adjudged to have good texture. Furthermore, hardness and fracturability are affected by the moisture contents and water activity. Hardness increased with decrease of moisture contents and showed a peak at 12.21% in AF packaging for formulation C. Moreover, the cereal bars can be considered as a well-balanced snack.

5.4 CONCLUSION

Hardness and fracturability of the PGR *Sunnah* cereal bars reduced with increase in moisture contents. Aluminium foil (AF) appeared to be the best packaging materials when compared to polyethylene terephthalate (PET), metallised polyester (MP) and nylon. The aluminium foil (AF) had good moisture barrier by considering the moisture contents and water activity values of the formulations with respect to the packaging materials. It also maintained the texture of the samples during the storage

period. It is the most appropriate for packing bars with respect to the product's stability. The cereal bars remained shelf stable when the moisture contents, water activity and textural properties of the bars were taken into consideration for the 120-day storage period. Incidence of hard texture during storage is the constraining factor for shelf life; however the product remained stable texturally during the entire storage period.

