# Forecasting Volatility of Quality Assessment for High Energy Biscuits (HEB) with ARCH Model

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**Abstract**

The High Energy Biscuits (HEB) products-310 data were collected from Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka over the year 2007 to 2012 in the method of single stage cluster sampling. Volatility as a measure of risk plays an important role in many qualitative decisions in such a situations. The main purpose of this study is to examine the volatility of the quality of High Energy Biscuits (HEB) products and its related stylized facts using Auto-regressive Conditional Heteoskedastic (ARCH) models. The physiochemical analysis data was used to study the volatility in the quality of High Energy Biscuits (HEB) products over a 5 years period. The adequacy of selected model tested using Auto-regressive Conditional Heteoskedastic-Lagrange Multiplier (ARCH-LM) test. The study concludes that ARCH model explains volatility of the quality of High Energy Biscuits (HEB) products.

**Keywords:** Volatility; ARCH models; ARCH-LM test; Quality of High Energy Biscuits (HEB) products; Single stage cluster sampling; Institute of Food Science and Technology (IFST).
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## 1. INTRODUCTION

World Food Programme (WFP) High Energy Biscuits (HEB) are biscuits (small baked bread or cakes) that are supplemented with a premix of vitamins and minerals. This ready to eat food participates to the covering of urgent needs in the acute phase of an emergency situation during which population is not able to cook due to a lack of access to basic facilities (clean water, cooking equipment…). Their use is also extended to a complement food ration (use as snacks) to provide vitamins and minerals in regions/population where diet is subjected to nutritional deficiencies. High Energy Biscuits (HEB) can be used also to prevent micronutrients deficiency of young children and school age children (Value, Fsc, & Food, n.d.).

Complete lists of mills and food processing factories can easily be found at the divisional level (contacting the local Chambers of Commerce, for eample) or by contacting the professional organizations or trade-unions. The lists here are the suppliers short listed by WFP.

| S.L. No. | Suppliers of Biscuits- Bangladesh |
|---|---|
| 1. | New Olympia Biscuit Factory |
| 2. | Masafi Bread & Biscuit Industries Ltd. |
| 3. | Resco Biscuit & Bread factory (PVT) Ltd. |
| 4. | Central Marketing Company (CMC) (Alauddin Food & Chemical Industries Ltd) |
| 5. | Mona Food Industries |
| 6. | Olympic Industries Limited |
| 7. | Romania Food & Beverages Ltd. |

(*Bangladesh Milling assesment additional info*, n.d.).

**1.1 Main ingredients:** High Energy Biscuits (HEB) must be manufactured from fresh and good quality, free from foreign materials, substances hazardous to health, excessive moisture, insect damage and fungal contamination and must comply with all relevant national food laws and standards (Van Hoan, 2013).

Requirements for the main ingredients are:

Wheat flour must conform toCodex STAN 152 (Standard, 1995).

Sugar must conform to Codex STAN 212-1999 (Stan, n.d.).

Shortening must be prepared from oil that conform to Codex STAN 210-1999, must be free from trans fatty acids and must contain only antioxidants that comply with Codex and relevant regulations (CODEX, n.d.).

Skimmed milk powder must conform to Codex STAN 207-1999. It must be accompanied by a ‘melamine-free’ certificate (Alimentarius, 1993).

Maximum level aflatoxin M1: < 0.5 mcg/kg milk (recommended methods ISO 14501/IDF 171:2007 (Reybroeck, Ooghe, Saul, & Salter, 2014) or ISO 14674/IDF 190:2005 ('ISO 14674:2005(en), Milk and milk powder — Determination of aflatoxin M1 content — Clean-up by immunoaffinity chromatography and determination by thin-layer chromatography', n.d.; Van Hoan, 2013).

**1.2 Key achievements in 2010:** School Feeding Program for Poverty Prone Areas in Bangladesh.

- Provided school feeding to 1,170,719 preprimary and primary school children (51 percent girls) in 9,965 schools.
- Each child received an average of 182 feeding days during the year, amounting to 8,191mt of high energy biscuits.
- Established 375 school gardens to demonstrate good homestead gardening practices and to deliver food and nutrition security messages.
- Increased female representation in School Management Committees from 18 percent in 2009 to 37 percent in 2010 (Report, 2010).

### 1.3 Auto-regressive Conditional Heteoskedastic Model (ARCH) model

ARCH (Auto-regressive Conditional Heteoskedastic) Model is the first and the basic model in stochastic variance modeling and is proposed by (R. F. Engle, 1982). The key point of this model is that it already changes the assumption of the variation in the error terms from constant $Var(\varepsilon_t) = \sigma^2$ to be a random sequence which depended on the past residuals ($\{\varepsilon_1 \dots \varepsilon_{t-1}\}$). That is to say, this model has changed the restriction from homoscedastic to be heteroscedasticity. This breakthrough is explained by (Baillie & Bollerslev, 1989). And this is an accurate change to reflect the volatility data's features. Let $\varepsilon_t$ as a random variable that has a mean and a variance conditionally on the information set $I_{t-1}$, The ARCH model of $\varepsilon_t$ has the following properties. Come from (Terasvirta, 2006).

First,

$E(\varepsilon_t | I_{t-1}) = 0$

And second, conditional variance

$$\sigma_t^2 = E(\varepsilon_t^2 / I_{t-1})$$

is a positive valued parametric function of $I_{t-1}$. The sequence $\{\varepsilon_t\}$ may be observed directly,or it may be got from the following formula. In the latter case, I can get

$\varepsilon_t = y_t - \mu_t(y_t)$

Where $y_t$ is observed value and $\mu_t(y_t) = E(y_t | I_{t-1})$ is the conditional mean of $y_t$given $I_{t-1}$, (R. F. Engle, 1982) application was of this type. In what follows, the $\varepsilon_t$ could beexpressed as another way on parametric forms of $\sigma_t^2$.

So, here $\varepsilon_t$ is assumed as follows:

$\varepsilon_t = z_t \sigma_t$

Where $\{z_t\}$ is a sequence of independent, identically distributed (iid) random variables with zero mean and unit variance. This implied:

$$\varepsilon_t \sim D(0, \sigma_t^2),$$

So the ARCH model of order q is like this:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots\dots\dots\dots + \alpha_q \varepsilon_{t-q}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2$$

Where $\alpha_0 > 0$, and $\alpha_i \geq 0$, $i > 0$. To assure $\{\sigma_t^2\}$ is asymptotically stationary random sequence, I can assume that $\alpha_1 + \dots + \alpha_q < 1$. This is the ARCH model.

With the generation of ARCH model, it already can explain many problems in many fields, for instance, interest rates, exchange rates and trade option and stock index returns. (Bollerslev, Chou, & Kroner, 1992) already used these models to achieve a variety of applications in their survey. It's different between forecasting the conditional variance of these series and forecasting the conditional mean of them because the conditional variance cannot be observed. So how to measure the conditional variance should be considered from (Andersen & Bollerslev, 1998).

The overall objective of the study is to model economic aspects of food production and analysis systems, understanding physiochemical analysis report and concernstakeholder awareness for food products. Specifically the study will pursue the following objectives: (i) to describe the physiochemical analysis of characteristics of food products; (ii) establish the determinants of food decision to accept in food products distinguishing between the fully-accepted food and unaccepted; (iii) elicit producer risk preferences and empirically analyze producer sources of risk and risk management strategies; (iv) explore consumer or stakeholder awareness, perceptions and attitudes regarding food products; and (v) identify the factors that affect the consumer's preference and consumption of food products. The outcome of which will help make policy recommendations that have an implication on technology adoption, increase smallholders capacity to bear risk and enable government and other role players have a clear understanding of consumers' food purchase decisions.

## 2. MATERIALS AND METHODS

### 2.1 Parameter estimation of ARCH model

There are several available methods for estimating the unknown parameters $\alpha_0$, $\alpha_1$, $\beta_1$ of the conditional variance processes above. Referring to (R. Engle, 1995), the ordinary least squares method could be used, however maximum likelihood is more efficient for estimation of the parameters.

The following loglikelihood function, l, could be maximized in order to estimate $\alpha_0$, $\alpha_1$ for ARCH(1) model and $\alpha_0$, $\alpha_1$, $\beta_1$ for GARCH(1,1) model.

$$l = \ln L = \ln(f(\varepsilon_1, \varepsilon_2, \ldots\ldots\ldots, \varepsilon_n | R_{t-1})) = \ln(\prod_{t=1}^{n} f(\varepsilon_t | R_{t-1}))$$

Assumed the process (3.49) with μ=0 and also assumed normal distribution of the conditional errors $\varepsilon_t \mid R_{t-1} \in N(0,\sigma_t)$ , the loglikelihood function is as follows:

$$l = -\frac{n}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{n}\ln\sigma_t^2 - \frac{1}{2}\sum_{t=1}^{n}\frac{R_t^2}{\sigma_t^2}$$

Taking into consideration the definitions of the conditional variances it gives us

$$l_{ARCH(1)} = -\frac{n}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{n}\ln(\alpha_0 + \alpha_1 R_{t-1}^2) - \frac{1}{2}\sum_{t=1}^{n}\frac{R_t^2}{(\alpha_0 + \alpha_1 R_{t-1}^2)}$$

Maximization of the functions above is to be done numerically with the inequality constrains (Kostavelis, 2012).

The basic version of the least squares model assumes that the expected value of all error terms, when squared, is the same at any given point. This assumption is called homoskedasticity, and it is this assumption that is the focus of ARCH/ GARCH models. Data in which the variances of the error terms are not equal, in which the error terms may reasonably be expected to be larger for some points or ranges of the data than for others, are said to suffer from heteroskedasticity. The standard warning is that in the presence of heteroskedasticity, the regression coefficients for an ordinary least squares regression are still unbiased, but the standard errors and confidence intervals estimated by conventional procedures will be too narrow, giving a false sense of precision. Instead of considering this as a problem to be corrected, ARCH and GARCH models treat heteroskedasticity as a variance to be modeled (R. Engle, 1982).

### 2.2 Properties of unconditional error terms

Recalling the fact that the unconditional mean value is equal to zero and the unconditional variance is not changing over time based on the law of iterated expectations

E[Y]=E[E[Y/X]]

where Y is a random variable and X is relevant known data. Assuming stationarity of the process, we can state for ARCH(1).

$$\sigma^2 = Var(\varepsilon_t) = E[\varepsilon_t^2] = E[E[\varepsilon_t^2 | R_{t-1}]] = E[\alpha_0 + \alpha_1\varepsilon_{t-1}^2] = \alpha_0 + \alpha_1 E[\varepsilon_{t-1}^2] = \frac{\alpha_0}{1-\alpha_1}$$

and also for GARCH(1,1) the unconditional variance could be expressed similarly

$$\sigma^2 = Var(\varepsilon_t) = E[\varepsilon_t^2] = E[E[\varepsilon_t^2 | R_{t-1}]] = \frac{\alpha_0}{1-\alpha_1-\beta_1}$$

(Kostavelis, 2012).

### 2.3 Residual Test/ ARCH LM Test

This is a Lagrange multiplier (LM) tests for autoregressive conditional hetroskedasticity (ARCH) in the residuals. The test statistic is computed by an auxiliary regression as follows.

$$P_t = \alpha_1 P_{t-1} + u_t \Rightarrow u_t = P_t - \alpha_1 P_{t-1}$$

To test the null hypothesis that there is no ARCH up to order q in the residuals, the following regression is run.

$$u_t^2 = \lambda_0 + \left(\sum_{s=1}^{q}\lambda_s u_{t-s}^2\right) + v_t$$

Where $u_t$ is the residual. This is a regression of the squared residuals on a constant and lagged squared residuals up to order q. The null hypothesis is that, $\lambda_s=0$ in the absence of ARCH components.

In a sample of T residuals under the null hypothesis of no ARCH errors, the LM test statistic equals number of observations*R-square ($TR^2$). The test statistic $TR^2$ follows Chi ($\chi^2$)-distribution with q (lag length) degrees of freedom. If $TR^2$ calculated is greater than the chi-square table value ($TR^2$ critical), reject the null hypothesis in favour of the alternate hypothesis. Hence there is ARCH effect in the GARCH model (Kuwornu, Mensah-Bonsu, & Ibrahim, 2011).

### 2.4 Unit Root Test

In the case of time series analysis, unit root tests are important. Unit root tests help to identify the stationarity and non-stationarity of time series data used for the study. A stationary time series has three basic properties. First, it has a finite mean. This means that a stationary series fluctuates around a constant long run mean. Second, a stationary time series has a finite variance. This means that variance is time invariant and third, a stationary time series has a finite (auto) covariance. This reflects that theoretical autocorrelation decay fast as lag length increases. Regressions run on non-stationary time Series produce a spurious relationship. Hence, to avoid a spurious relationship, there is a need to perform a unit root test on variables (Hye & Ali, 2009). This thesis uses Dickey–Fuller (DF) test for performing unit root tests.

Dickey – Fuller (DF) has been widely used to check the stationarity and presence of unit root of a process. The Dickey – Fuller test is valid only for AR(1). We usethe DF test when the residual are not autocorrelated. Dickey – Fuller considered theestimation of the parameter α from the models.

1. $y_t = \alpha y_{t-1} + e_t$ (pure random walk)
2. $y_t = \mu+\alpha y_{t-1} + e_t$ (drift + random walk)
3. $y_t = \mu+bt+\alpha y_{t-1} + e_t$ (drift + linear trend)

It assumes that $y_0=0$ and $e_t \sim$i.i.d $(0, \sigma^2)$

The null and alternative hypotheses are:

$H_0$: α=1 (α(z)=0 has a unit root)

$H_1$: |α |<1 (α(z)=0 has root outside unit circle)(Mahadeva & Robinson, 2004; Pantelis & Zehtabchi, 2008). Using non-stationary time series data in financial models produces unreliable and spurious results and leads to poor understanding and forecasting ('Introduction To Stationary And Non-Stationary Processes | Investopedia', n.d.).

### 2.5 Data

The High Energy Biscuits (HEB) products analysed 310 observations were collected from different analytical laboratory of Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR) over the year from 2007 to 2012 by Single Stage Cluster Sampling method (Institute of Food Science and Technology (IFST), BCSIR, 2010).

## 3. RESULTS AND DISCUSSION

### 3.1 ARCH-LM test

To detect the presence of ARCH effect in the mean equation of Fortified High Energy Biscuits we use the ARCH-LM (Lagrange multiplier) test.

**Table 1. ARCH-LM and DF test analysis results of chemical analysis of Fortified High Energy Biscuits (HEB).**

| Variable | LM test for autoregressive conditional heteroskedasticity (ARCH) | | Dickey-Fuller test for unit root | |
|---|---|---|---|---|
| | Chi-square Statistic | P-value | Test Statistic, Z(t) | P-value |
| Moisture (%) | 0.255 | 0.6136 | -16.497 | 0.000 |
| Protein (%) | 3.706 | 0.0542 | -15.953 | 0.000 |
| Fat (%) | 0.380 | 0.5377 | -16.910 | 0.000 |
| Sugar (%) | 0.047 | 0.8283 | -15.074 | 0.000 |
| Total Carbohydrate (%) | 0.332 | 0.5644 | -17.445 | 0.000 |
| Iron (mg/100g) | 62.038 | 0.0000 | -7.515 | 0.000 |
| Vitamin A (mcg/100g) | 158.344 | 0.0000 | -6.167 | 0.000 |
| Mesophyllic aerobic bacteria (cfu/g) | 7.708 | 0.0055 | -6.911 | 0.000 |
| Bacillus cereus (cfu/g) | 0.309 | 0.5786 | -9.992 | 0.000 |
| Enterobacter sakazakii (cfu/g) | 0.046 | 0.8296 | -9.612 | 0.000 |
| Yeast and moulds (cfu/g) | 0.012 | 0.9142 | -9.403 | 0.000 |

In our analysis the different value for different variables of above parameters of the ARCH-LM test in the lags 1. The corresponding P-Value is <0.05, which is very low for Iron (mg/100g), Vitamin A (mcg/100g) and

Mesophyllic aerobic bacteria (cfu/g). So we have no difficulty to reject the null hypothesis of no ARCH error, and conclude that there is an ARCH error in the analysis. This confirms that the ARCH error in the variable of biscuit products. Others parameters are insignificant that means no ARCH effects of the models. The estimation results are given in the table 1.

Table 1 shows that the values of DF test for all variables p-value <0.05 at 5%, level of significance which implies that the variables series is stationary. An outcome of DF test confirms that the physiochemical analysis variables series is stationary.

### 3.2 Spike Behaviour of ARCH(1) and GARCH(1,1) model estimations

The presence of extreme spikes in our analysis of biscuit products that is a bad characteristic of food products.

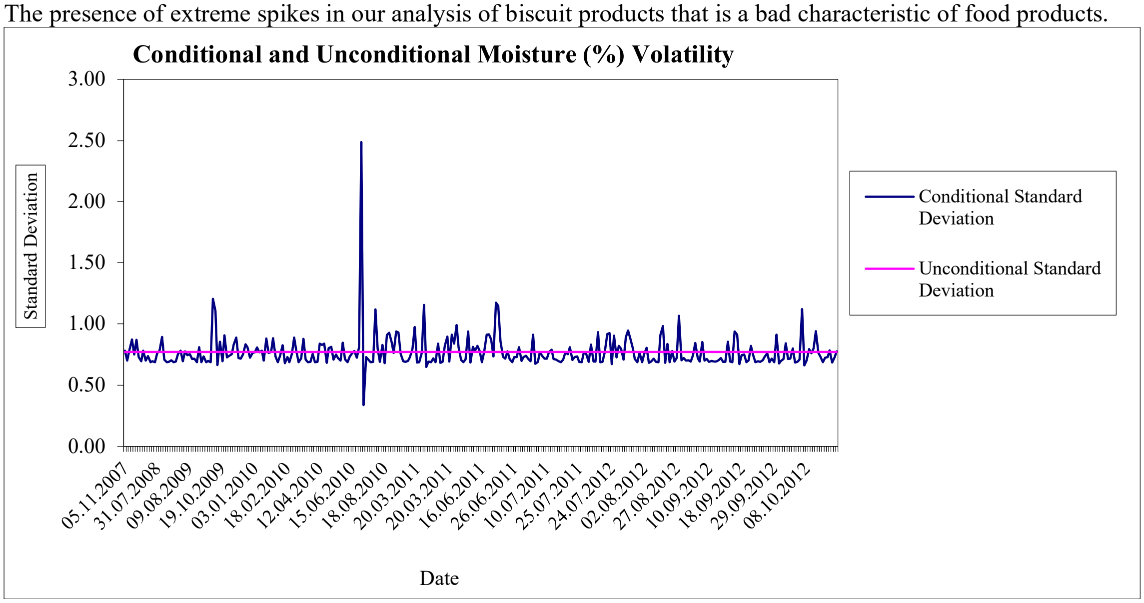


**Figure 1. Moisture (%) content of biscuit products for the period November 2007 to November 2012.**

Figure 1 shows the conditional and unconditional standard deviation of Moisture (%) content over the period November 2007 to November 2012. Conditional standard deviations are over 0.33 during the sample period. The results indicate that the standard deviation almost stable among 2007 to 2012 and in spike behaviour in 2010. However, volatility in deviations is very low in this time period.

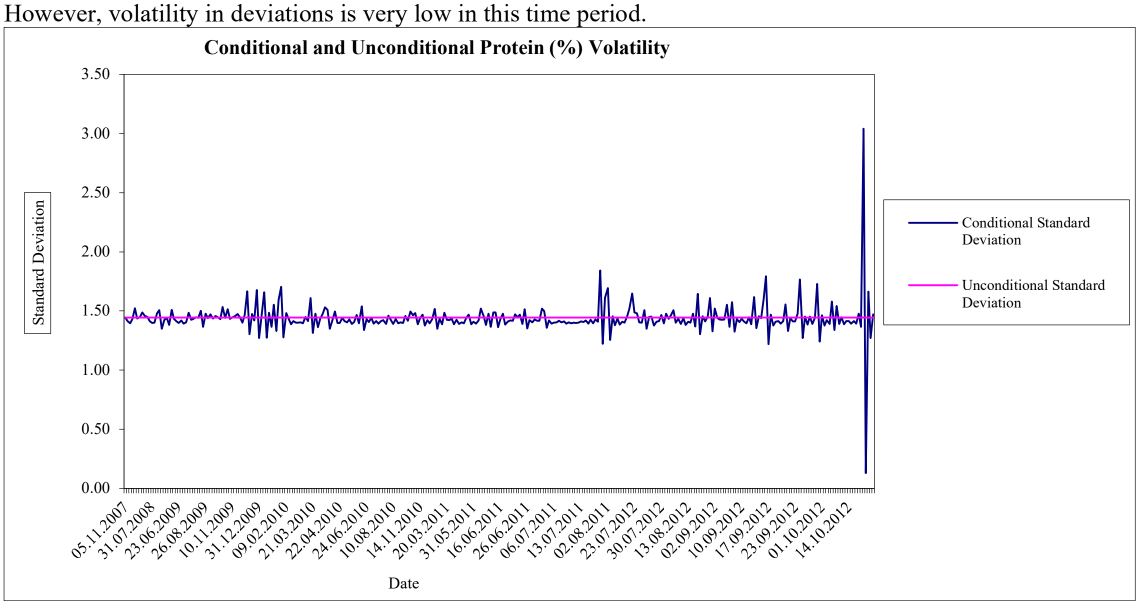


**Figure 2. Protein (%) content of biscuit products for the period November 2007 to October 2012.**

Figure 2 shows the conditional and unconditional standard deviation of Protein (%) content over the period November 2007 to October 2012. Conditional standard deviations are over 0.12 during the sample period. The results indicate that the deviations increased significantly between 2010 and 2012 and decreased between 2007-

2009 and 2010-2011 and also in spike behaviour at the end of 2012. However, volatility in deviation is low in this time period.

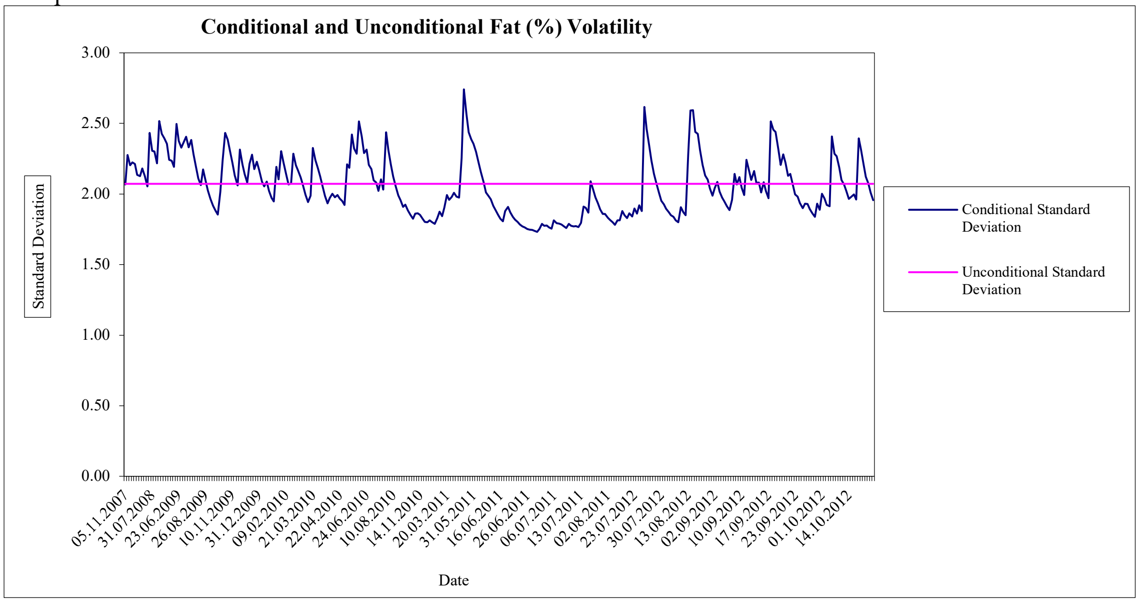


**Figure 3. Fat (%) content of biscuit products for the period November 2007 to October 2012.**

Figure 3 shows the conditional and unconditional standard deviation of Fat (%) content over the period November 2007 to October 2012. Conditional standard deviations are over 1.5 during the sample period. As can be seen in Fig. 3, the deviation is relatively stable upto 2011 and increasing after 2012.

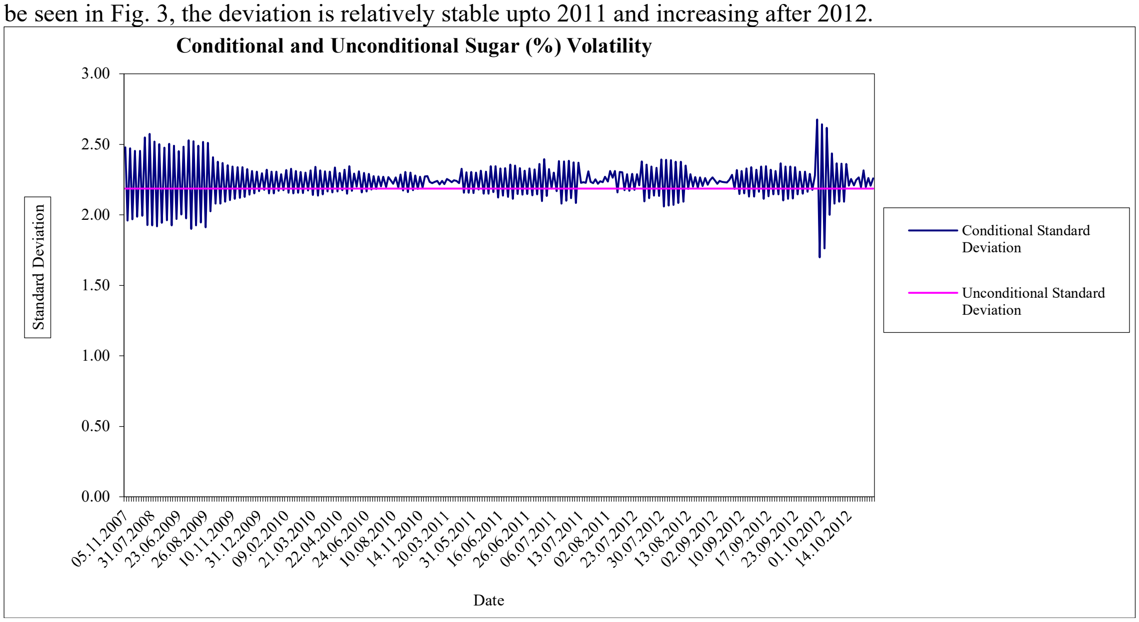


**Figure 4. Sugar (%) content of biscuit products for the period November 2007 to October 2012.**

Figure 4 shows the conditional and unconditional standard deviation of Sugar (%) content over the period November 2007 to October 2012. Conditional deviations are over 1.5 during the sampling period. The results indicate that fluctuations of contional standard deviation between 2007 -2012 and also increasing at the end of 2012. However, volatility in deviations is low in this time period. The deviations show spike behaviour during the period 2007-2009 and at the end of 2012.

 

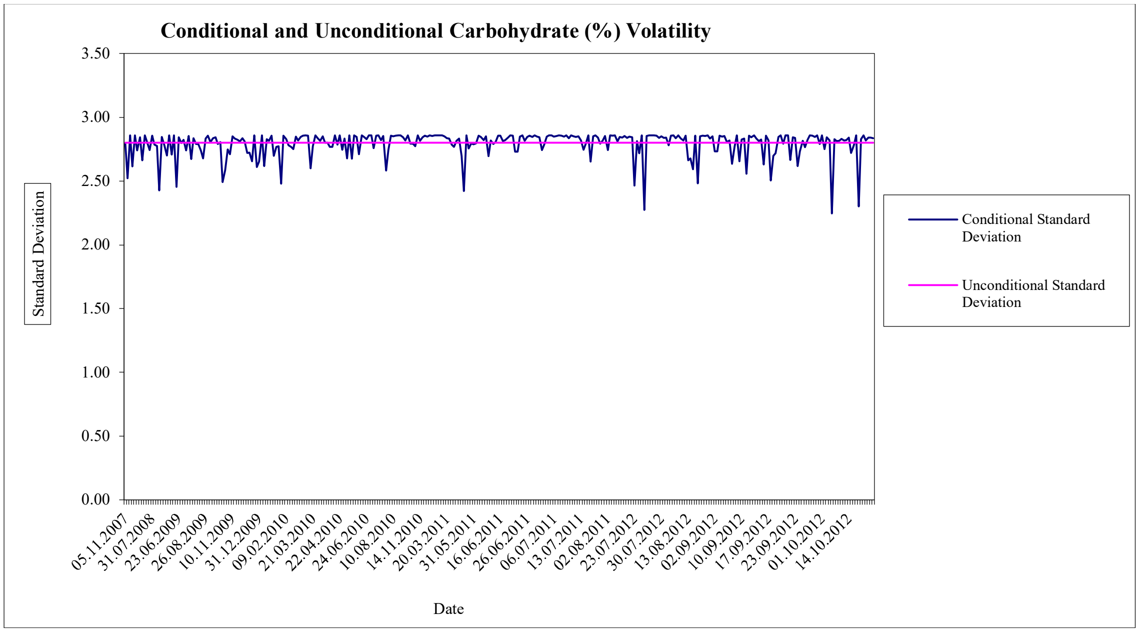


**Figure 5. Total Carbohydrate (%) content of biscuit products for the period November 2007 to October 2012.**

Figure 5 shows conditional and unconditional standard deviation of Total Carbohydrate (%) content over the period November 2007 to October 2012. Conditional deviations are over 2.00 during the sampling period. As can be seen in Fig. 5, the deviation relatively stable during sampling period. However, volatility in deviation is low in this time period. The deviation show spike behaviour during the period 2007–2012.

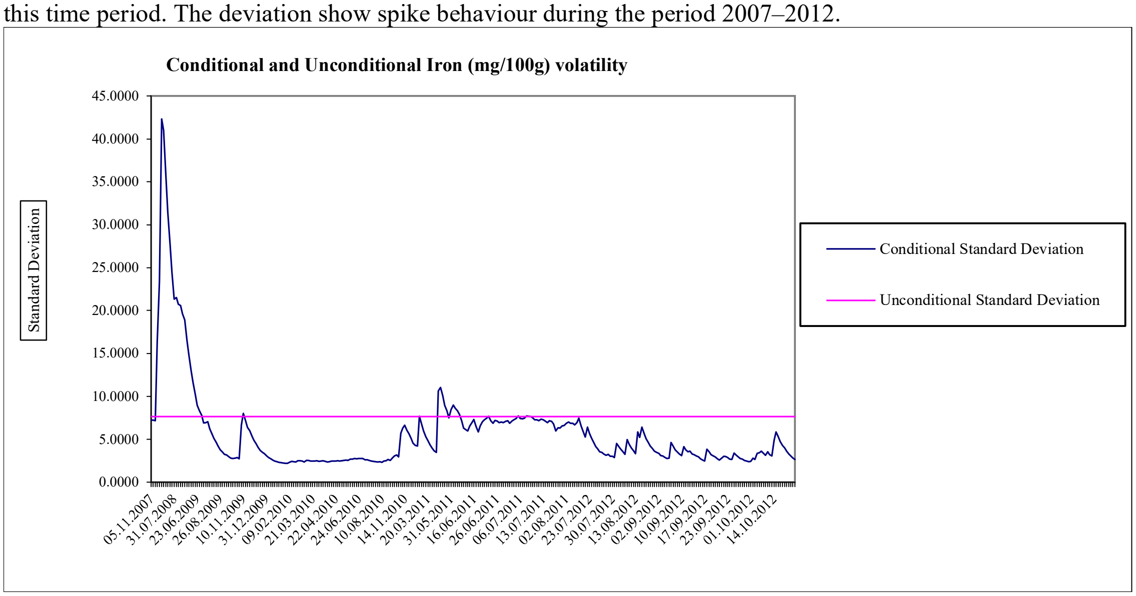


**Figure 6. Iron (mg/100g) content of biscuit products for the Period November 2007 to October 2012.**

Figure 6 shows the conditional and unconditional standard deviation of Iron (mg/100g) content over the period November 2007 to October 2012. Conditional deviations are over 2.00 during the sample period. The results indicate that the deviations are highly spike behaviour at first of the period 2007. As can be seen in Fig. 6, the deviation has a decreasing trend between 2009 -12.

 

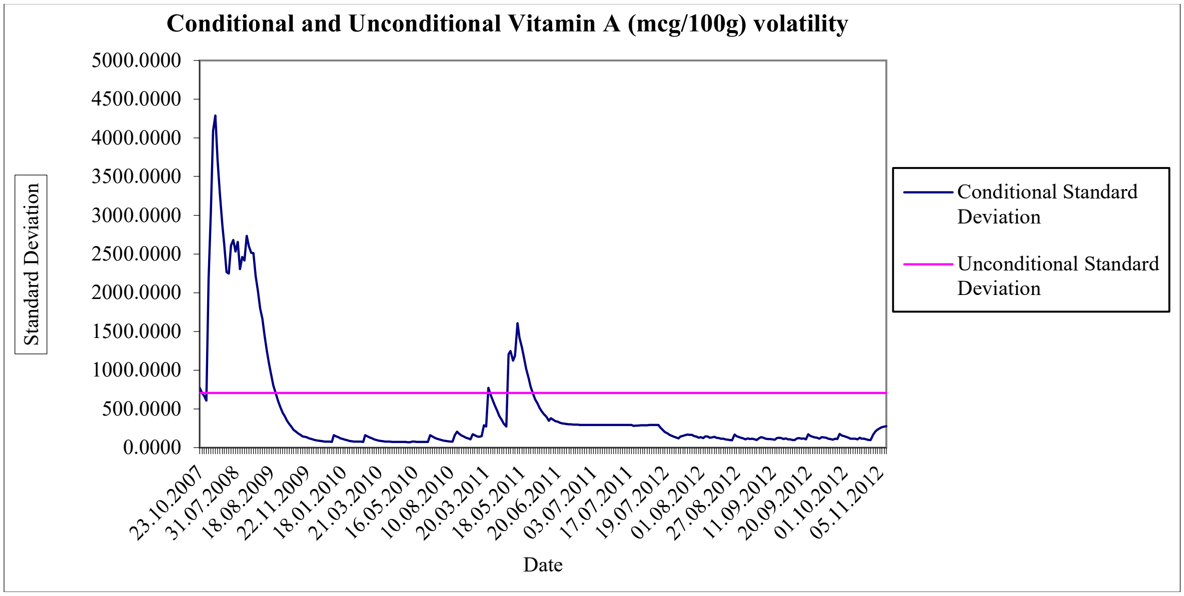


**Figure 7. Vitamin A (mcg/100g) content of biscuit products for the Period November 2007 to October 2012.**

Figure 7 shows the conditional and unconditional standard deviation of Vitamin A (mcg/100g) content over the period November 2007 to October 2012. Conditional deviations are over 80.00 during the sampling period. The results indicate that the deviations show highly spike behaviour at during 2007 and 2011 and relatively stable during after 2012. As can be seen in Fig. 7, the deviation has a decreasing after june 2009 -2012.

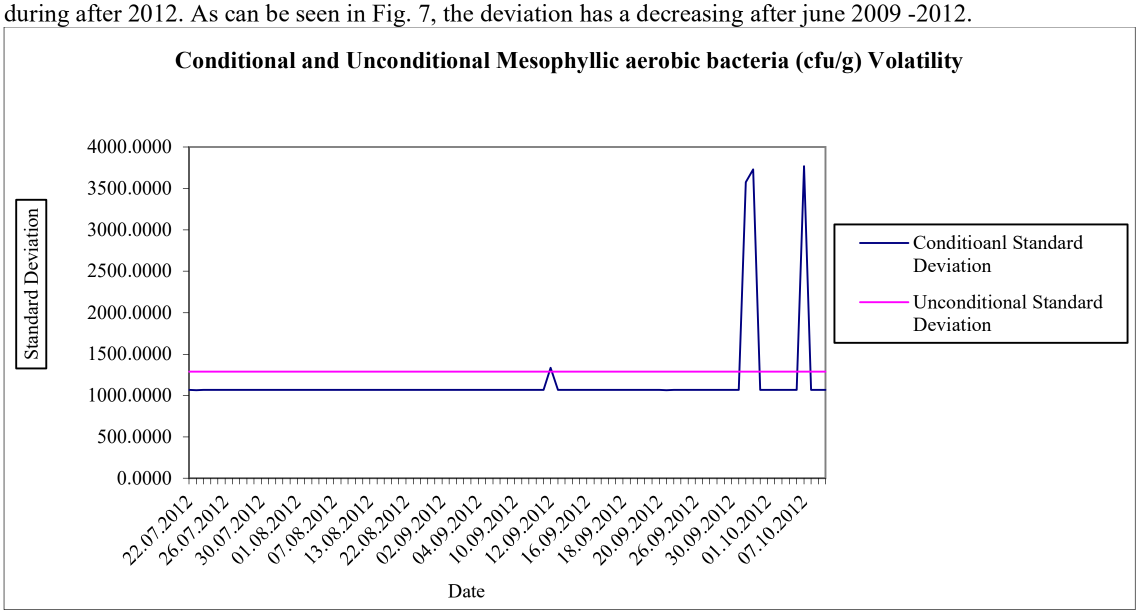


**Figure 8. Mesophyllic aerobic bacteria (cfu/g) content of biscuit products for the Period July 2012 to October 2012.**

Figure 8 shows the conditional and unconditional standard deviation of Mesophyllic aerobic bacteria (cfu/g) content over the period July 2012 to October 2012. Conditional deviations are over 1000.00 during the sample period. The results indicate that the deviations have two peak spike behaviour at the end 2012 and relatively stable during the others period of 2012.

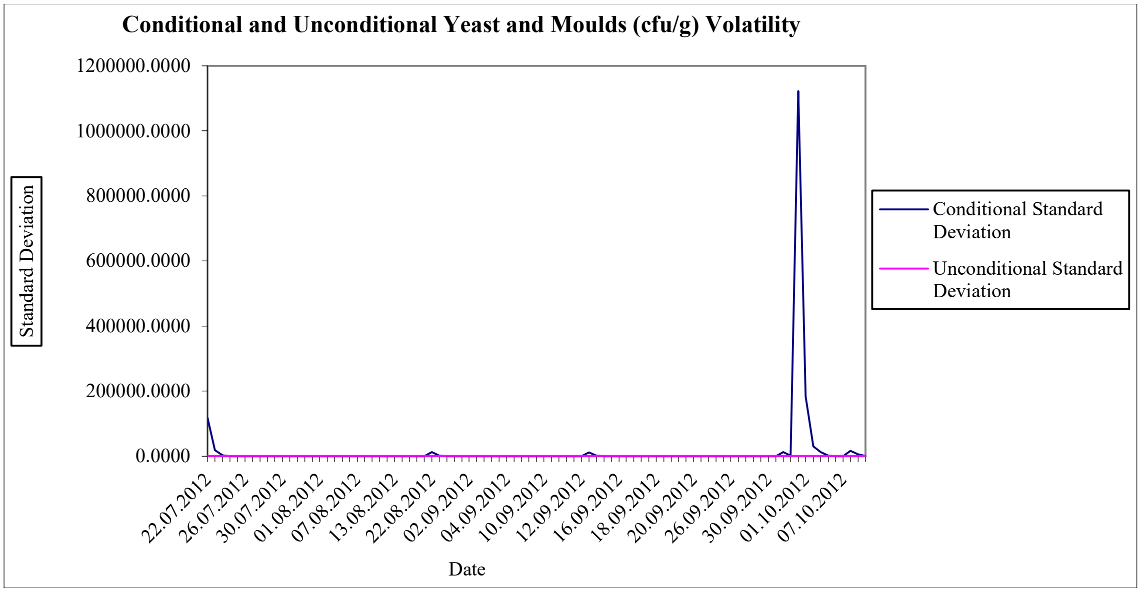


**Figure 9. Yeast and Moulds (cfu/g) content of biscuit products for the Period July 2012 to October 2012.**

Figure 9 shows the conditional and unconditional standard deviation of Yeast and Moulds (cfu/g) content over the period July 2012 to October 2012. Conditional deviations are over 0.00 during the sample period. The results indicate that the deviations have a high spike behaviour at the end of the period 2012 and relatively stable during the others periods.

The results of figure 1 to 9 indicate that the volatility in the high energy biscuits (HEB) exhibits the low or stable of volatility in this time period.

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## 5. CONCLUTION AND RECOMMENDATIONS

This study attempted to study the volatility in the quality of food products. The analyzed data were collected for the use of statistical technique over the period of 2007 to 2012. Empirical results showed that ARCH model can adequately describe the quality of food products. We use ARCH-LM test to test whether there is any further ARCH error in both series. The test results of some parameters in High Energy Biscuits (HEB) products show that there is there is an ARCH error in the analysis series. The results suggest that the volatility in the quality of High Energy Biscuits (HEB) products exhibits the persistence of volatility behavior. Our results revealed that the ARCH model satisfactorily explains volatility and is the most appropriate model for explaining volatility in the series under analysis. Government mechanism should continuously monitor the food products quality in Bangladesh on a regular basis for necessary analysis of the contents of High Energy Biscuits (HEB) products. For this purpose regular sample analysis data should be collected and necessary statistical analysis should be done. Partnerships with relevant academic and research institutions to investigate and to generate information and data. This relevant organization should maintain a data bank of food products produced in our country for further statistical analysis.

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